LESSON 2. MAJOR UNITS OF THE NIKE HERCULES MISSILE

MMS Subcourse No 900 . . . . **Nike Missile Maintenance**

Lesson Objective . . . . **To provide you with a general knowledge of the basic functions of units in the Nike Hercules Missile to include the rocket motor cluster, missile rocket motor, hydraulic system, guidance system, and the warhead system.**

Credit Hours . . . . **Three**

TEXT

1. INTRODUCTION.

a. In the previous lesson, we discussed some of the general characteristics of the Nike Hercules missile. During that discussion you probably asked yourself: How does the missile translate the command from the radar into elevon movement? How does the missile orient itself so it "knows" which elevons to move to execute a given command? How does the missile rocket motor ignite upon booster separation? These and many similar questions will be answered in this lesson.

b. You will remember that the Nike Hercules is a two-stage solid propellant guided missile. You will also recall that the physical configuration of the missile is broken down into several sections. In this lesson, we will depart from the physical considerations and examine the things that make the missile "tick", the functional groups. There are five such groups or systems: (1) Rocket motor cluster, (2) Missile rocket motor, (3) Guidance system, (4) Hydraulic system, and (5) Warhead system.

2. ROCKET MOTOR CLUSTER.

a. General. The rocket motor cluster (fig 1) is a solid propellant booster unit approximately 14 feet long. It houses four clustered rocket motors, and is equipped with 4 fins in a cruciform configuration.

b. Major components. The major components of the rocket motor cluster are: (1) rocket motor thrust ring assembly, (2) four rocket motors, (3) four rocket motor igniters, (4) four rocket cluster fins, and (5) four fitting assemblies, and (6) fairings.

c. Rocket motor thrust ring assembly. This assembly mates the missile to the rocket motor cluster. It has an opening that is properly tapered to receive the boattail of the missile, thereby forming a rigid slip-joint. Relative motion between the missile and rocket motor cluster is prevented by an indexing pin on the boattail which engages a recess in the thrust structure (fig 2). Four elevon locks are attached to the forward end of the thrust ring assembly. The elevon locks hold the missiles elevons in the trimmed condition during the boost phase.

d. Rocket motor. The four rocket motors are identical; therefore, only one will be discussed. The rocket motor consists of a solid propellant encased by a steel cylinder, with a steel enclosure at the forward end and a steel nozzle at the rear end (fig 3).

(1) The solid propellant is cast into a symmetrical configuration (fig 3,A). Each of the nine gas passages contains a resonance rod to insure uniform propellant burning. An inhibited cellulose acetate liner surrounds the propellant to prevent burning on the

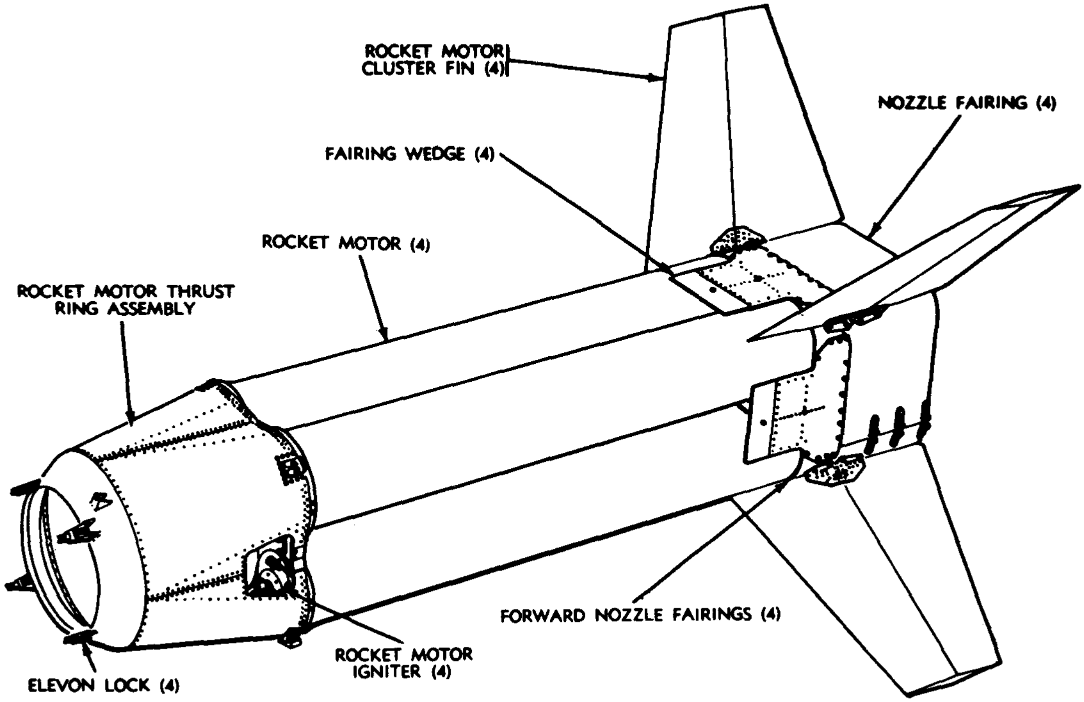


Figure 1. Rocket motor cluster, major components.

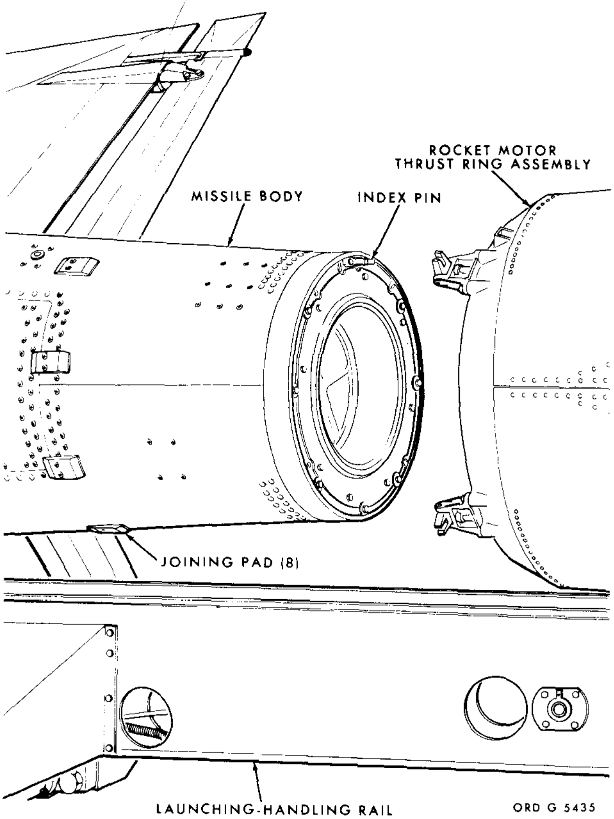


Figure 2. Missile body and rocket motor cluster.

outside of the propellant. An insulating coating on the surface of the combustion chamber protects the wall and the surrounding area from the high heat generated by the combustion of the propellant.

(2) Prior to firing, the propellant is protected from the outside elements by the seal furnished by a nozzle closure. The seal is blown out when the rocket motor ignites.

(3) During propellant combustion, the hot gases generated escape through the nozzle at high velocities. The escaping gases provide the thrust required to propel the missile during the boost phase.

e. Rocket motor igniters.

(1) Each rocket motor has an igniter (fig 3,B) located at its forward end. The igniter consists of 2.2 pounds of explosive charge housed in a polystyrene cup. Approximately one-half second after launch order, an electrical current is applied to each igniter, firing the explosive charge. This explosion ignites the propellant in the rocket motors.

(2) A shorting connector is inserted across the electrical inputs to the igniter to prevent stray voltages

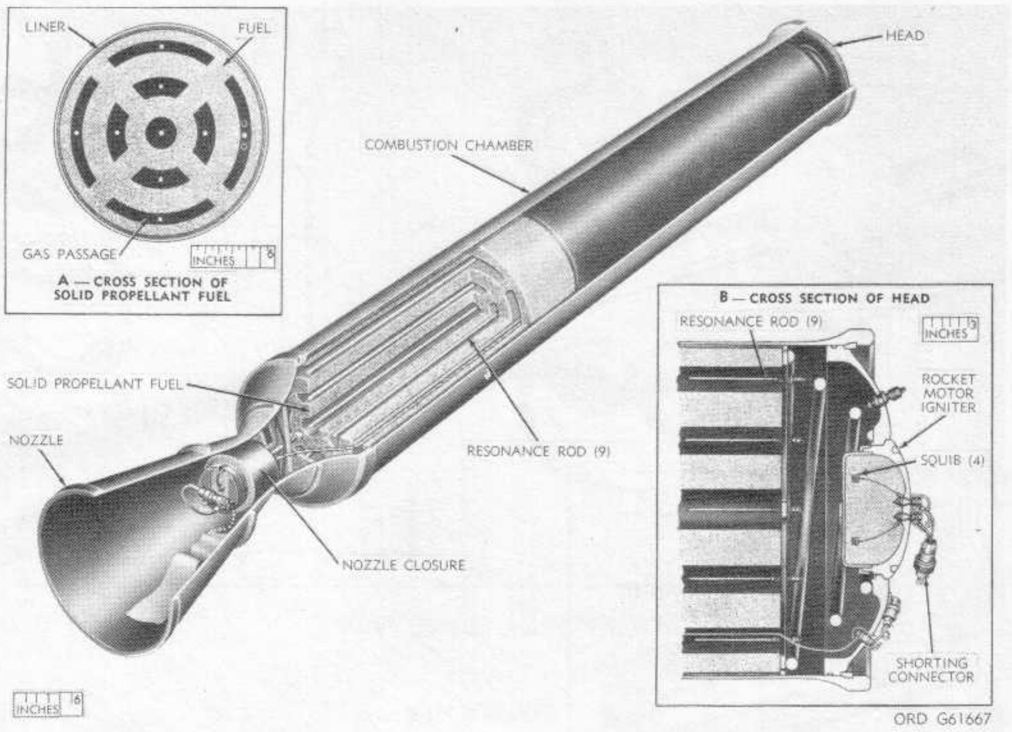


Figure 3. Rocket motor, cutaway view.

from igniting the propellant. The shorting connector is removed after the missile has been made ready for firing. The rocket motor igniter is removed during shipment to prevent accidental ignition of the propellant.

f. Rocket motor cluster fins. The rocket motor cluster fins are placed at 90° angles around the rear portion of the rocket motor cluster. They provide aerodynamic stability during the boost phase. The fins are constructed of aluminum and are riveted to the structural frame of the missile.

g. Fitting assemblies and fairings. Four forward nozzle fairings, four fairing wedges, and four nozzle fairings are attached to the fitting assemblies to improve the aerodynamic stability of the rocket motor cluster.

3. MISSILE ROCKET MOTOR.

a. General. The missile rocket motor M30 (fig 4) is ignited after booster separation to provide the final thrust. Its primary components are: (1) Gas generator, (2) Combustion chamber, (3) Blast tube, and (4) Blast tube nozzle.

b. Gas generator (fig 4,A). The gas generator produces hot burning gases used to ignite the solid propellant in the combustion chamber. It is activated by the two initiators at booster separation.

(1) During the boost period, acceleration acting on the safe and arm switch provides the force required to arm it. After booster burnout, booster separation occurs because of the air drag on the rocket motor cluster. The booster falling away pulls the propulsion arming lanyard. In turn, the lanyard activates the thermal batteries. The batteries develop enough voltage in less than one second to ignite the initiators.

(2) The initiators ignite a pellet charge in the forward end of the gas generator. The pressure resulting from the ignition of the pellet ruptures the diaphragm, and combustion rapidly spreads to the ignition chamber of the gas generator. Hot burning gases are forced from the ignition chamber through the nozzle into the rocket motor's combustion chamber, igniting the fuel.

c. Combustion chamber. The steel combustion chamber houses the solid propellant fuel (fig 4,B). An

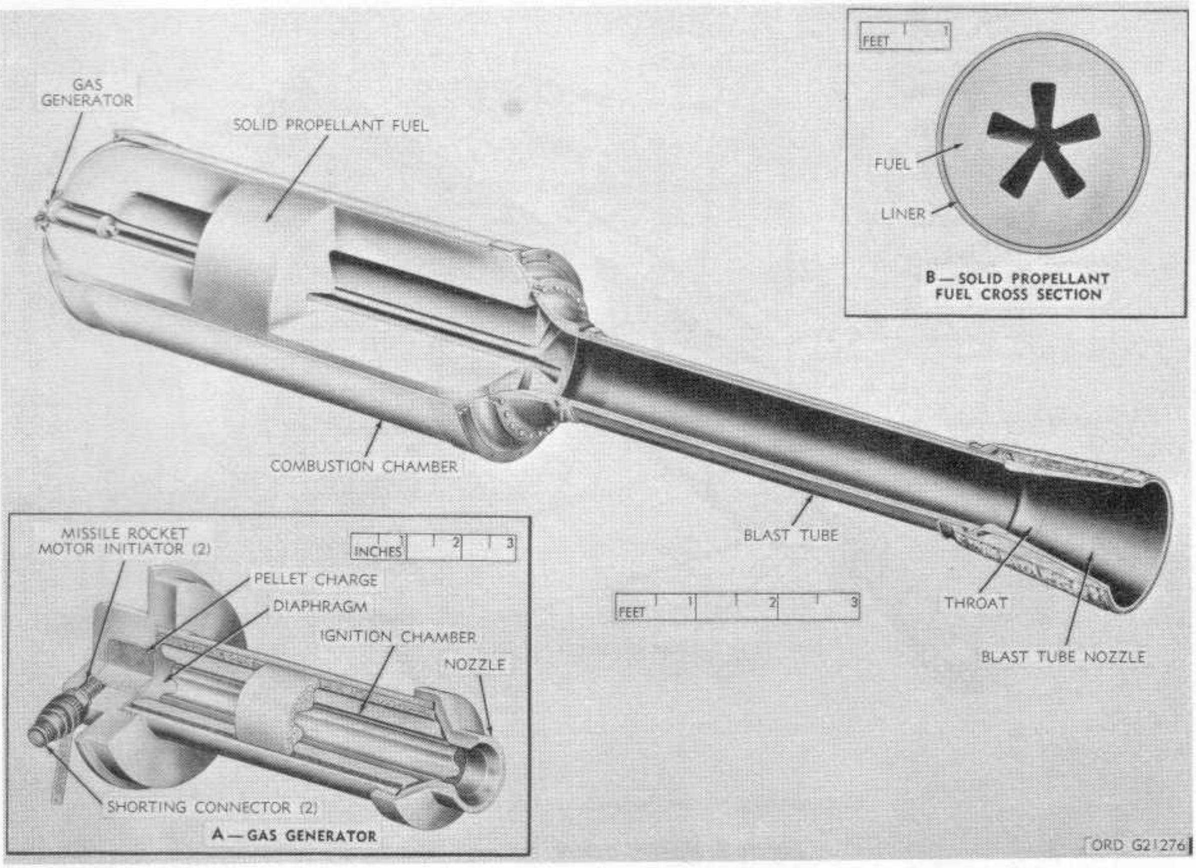


Figure 4. Missile rocket motor M30, cutaway view.

inhibited cellulose acetate liner protects the wall of the combustion chambers from the heat generated.

d. Blast tube. The blast tube directs the hot gases of combustion to the blast tube nozzle. Use of the blast tube allows the combustion chamber to be placed near the center of the missile for weight distribution purposes.

e. Blast tube nozzle. The hot gases are directed from the blast tube out the blast tube nozzle to provide the thrust required to propel the missile from booster separation time to detonation time.

f. Safety devices. Firing of the rocket motor initiators is prevented before the boost period by shorting across their input with the safe and arm switch. This switch also opens the circuit to the voltage source until the proper acceleration is reached. Other precautionary measures are taken against premature ignition as described in 2e(2) above.

4. GUIDANCE SYSTEM.

a. General. The missile guidance set group (fig 5) controls the flight of the missile by driving the hydraulic system that positions the elevons. It receives its inputs from two sources: the command inputs from the MTR, and flight stabilization inputs generated within the missile itself.

b. Types of commands. There are basically two types of commands received by the guidance system: flight attitude commands and the burst or detonation command. Flight attitude commands are further broken down into yaw (Y), pitch (P), and roll commands.

c. Yaw, pitch, and roll. In the normal sense, yaw refers to the left-right control and pitch to the up-down control (fig 6,A). Notice that the orientation of these control surfaces is critical. If the missile were to rotate by 90°, yaw commands would result in pitch movements, and vice-versa. It is the function of the roll commands to keep the missile in the proper orientation at all times. The roll commands are generated within the missile; however, the yaw, pitch, and burst commands are received from the MTR.

d. Missile orientation. Actually, the missile does

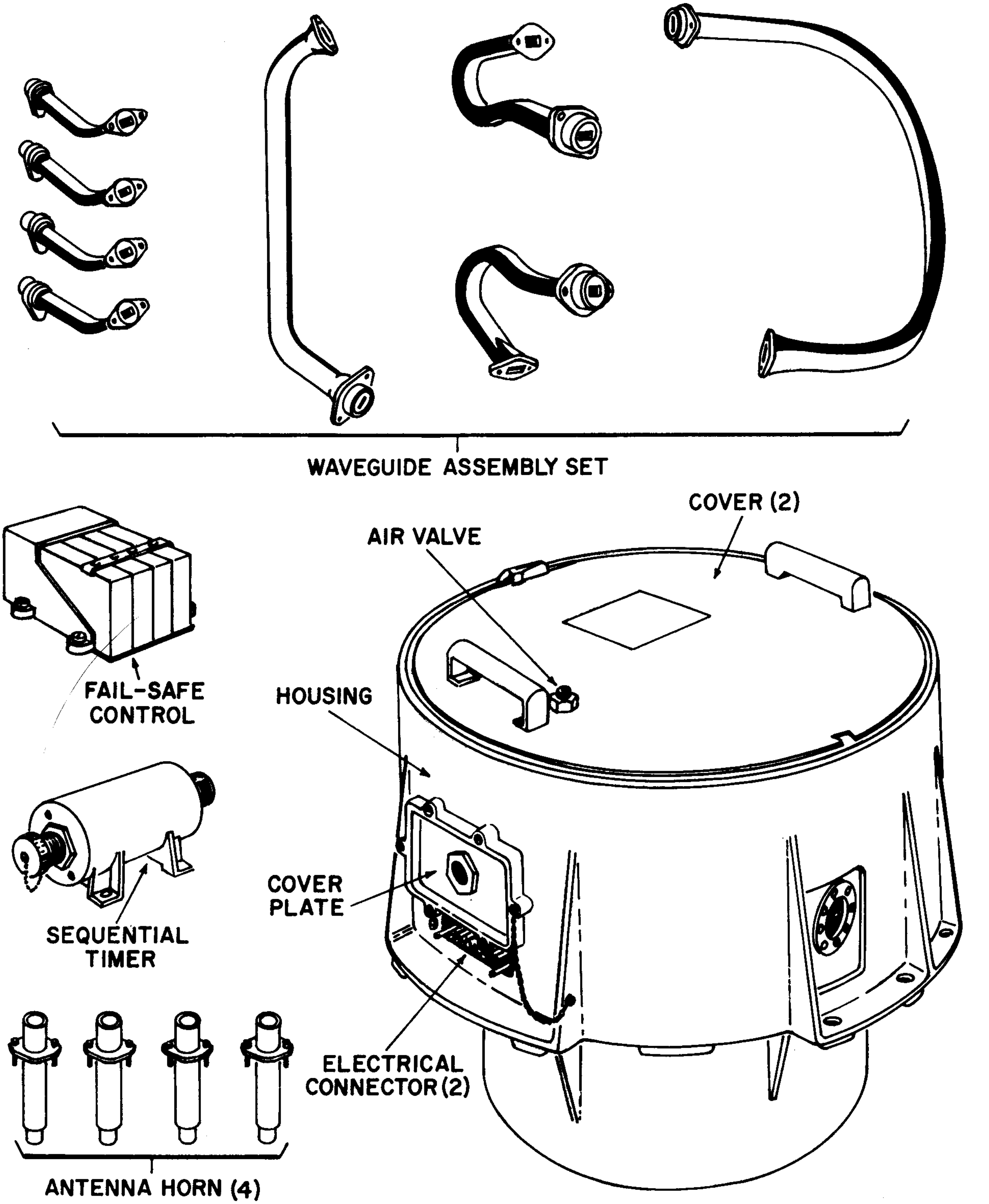


Figure 5. Missile guidance set group.

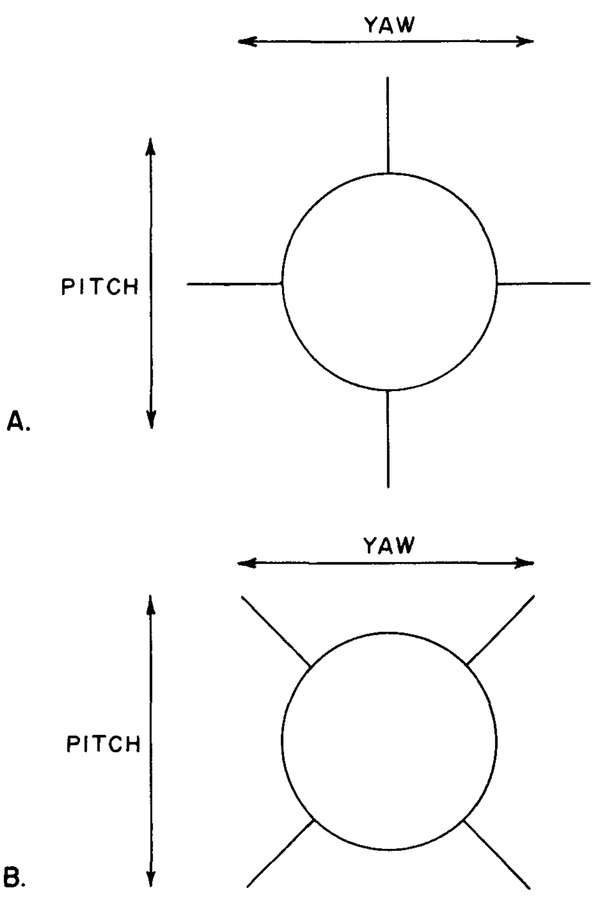
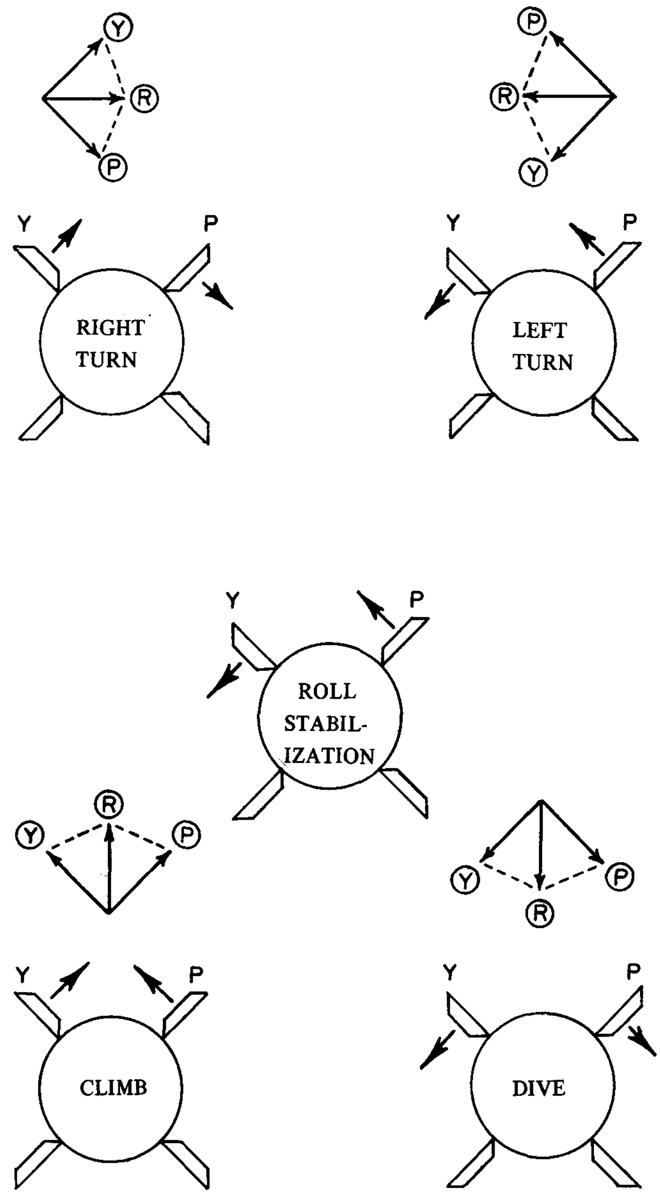


Figure 6. Cruciform control surface configuration.

not fly in the orientation shown in figure 6A, but assumes instead the attitude shown in figure 6B. With the missile in this attitude, it is apparent, from inspection of figure 7, that either a pitch or yaw movement may be caused by the proper combination of all four control surfaces. However, for the purposes of the following description, we will assume "pure" pitch and yaw commands.

e. Simplified block diagram of the guidance and control system (fig 8). The major unit of the guidance set is the Transponder-control group. The primary functions of the transponder-control group are to receive and decode the commands, and to route the proper signals to the hydraulic system for flight control and to the warhead system for detonation control. The principle subunits of the transponder-control group are the radio set and the flight control group.

(1) The radio set receives the yaw and pitch commands from the MTR and decodes them into the proper signals to drive the hydraulic system. For each properly received set of coded information, the radio set



P = PITCH ELEVON PAIR

Y = YAW ELEVON PAIR

(P) = PITCH COMMAND

(Y) = YAW COMMAND

(R) = RESULTANT

Figure 7. Elevon displacement and resulting flight movement.

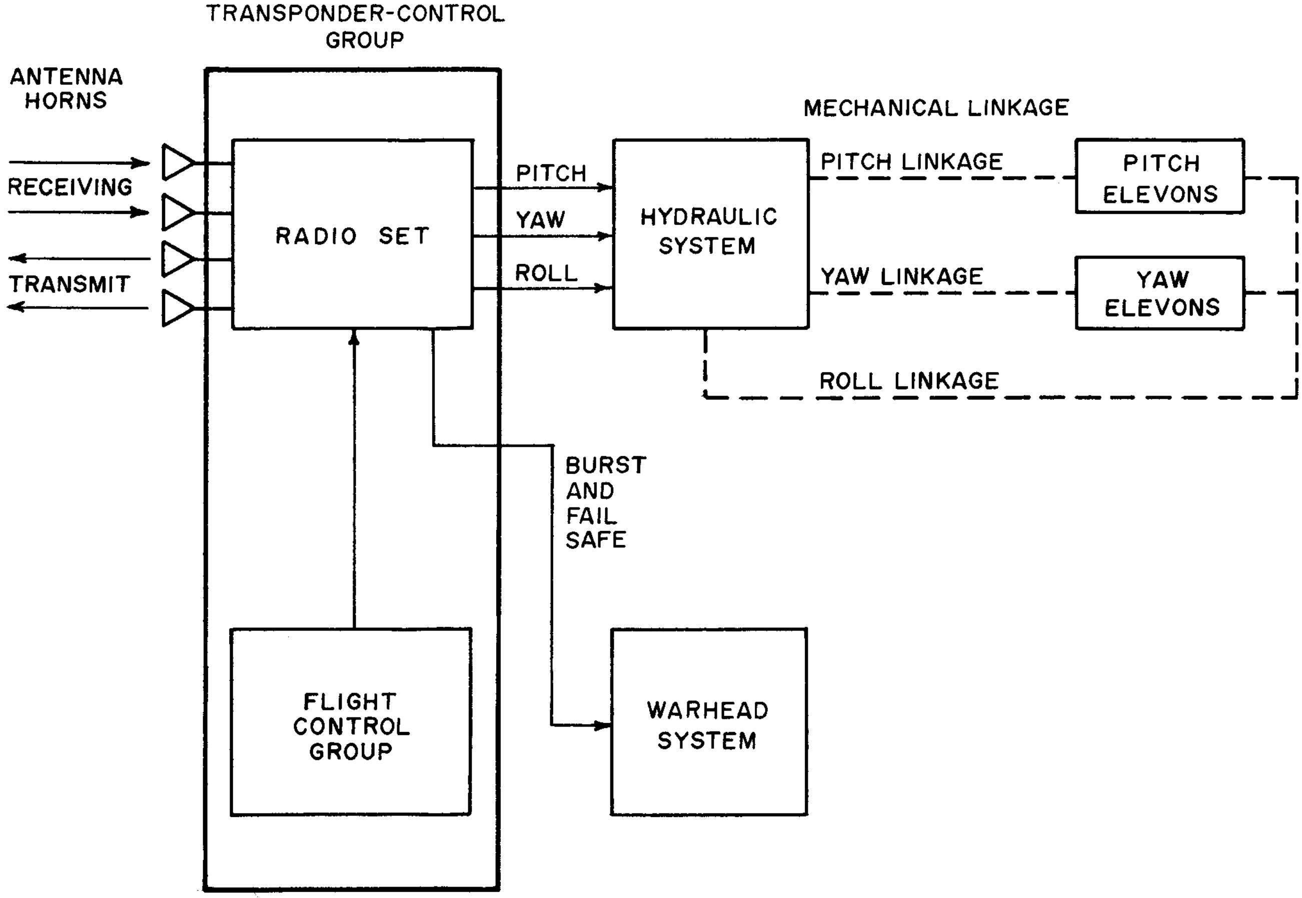


Figure 8. Simplified block diagram of the guidance and control system.

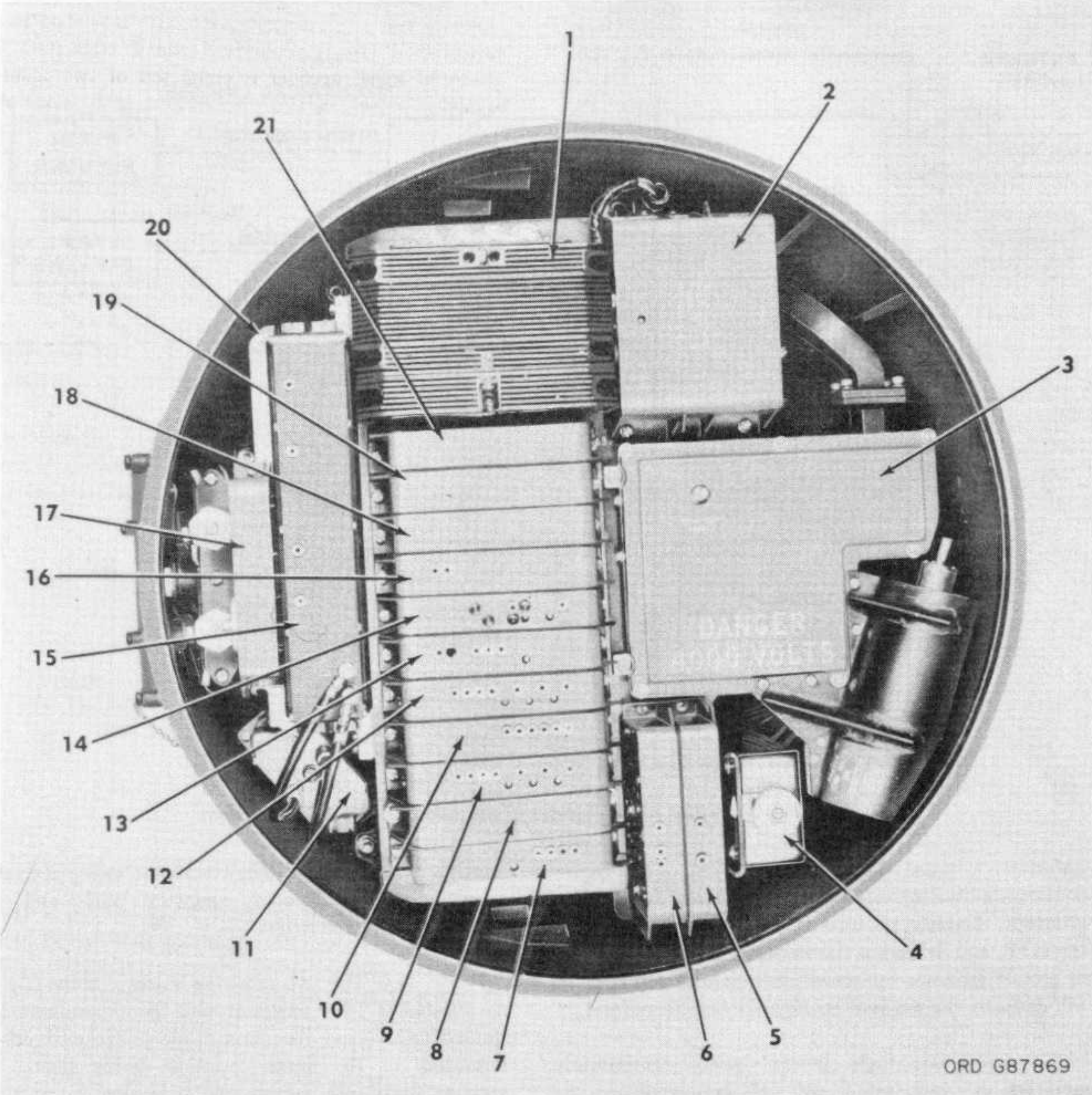
transmits a signal back to the MTR. This insures continuous tracking throughout the mission. Just prior to intercept, the radio set receives the burst command from the MTR, and detonates the warhead. If the guidance set or ground guidance equipment malfunctions, the radio set will detonate the warhead through the fail safe control.

(2) The flight control group continuously monitors the yaw, pitch, and roll movements of the missile. One function of this equipment is to insure the missile maintains the proper roll attitude. Notice that roll linkage drives both the yaw and pitch elevons. The center drawing in figure 7 shows roll stabilization. Secondly, if the yaw or pitch commands are too severe, the flight control group will compensate by reducing the amount of control applied to the hydraulic system. Also housed within this group is a pressure sensitive device that modifies elevon deflection as a function of altitude and speed.

f. Radio set (fig 9). The receiving and decoding circuits consist of two receiving antenna horns (fig 10), two transmitting antenna horns, a radio receiver, an amplifier decoder, pulse delay oscillator, sweep generator, command signal decoder, and the pitch and yaw command signal converters.

(1) The two receiving antenna horns (fig 10) are located at 180° angles around the circumference of the missile to insure reception of the guidance commands regardless of the missile position during flight. The antenna horns use polystyrene polarizers to vertically polarize the RF energy with respect to the waveguide in the missile, regardless of the missile roll angle. The vertically polarized RF energy is fed through the waveguide to the radio receiver.

(2) The radio receiver (fig 10) consists of two detector cavities, each cavity containing a crystal detector. Each cavity provides a low Q resonant circuit in the frequency range of the missile tracking radar transmitter. The resonant cavity represents a low impedance to frequencies outside the range of the missile and limits the reception to desired frequencies. The crystal detectors convert the received RF energy into direct current (DC) pulses. The resulting DC pulses are applied to the



1. Radio set power supply
2. Transistor oscillator inverter
3. Radio transmitter
4. Missile-code delay line
5. RF detector
6. Delay line driver
7. Command detonation electronic switch
8. P-Y-burst delay network
9. Y command signal converter
10. Command signal decoder
11. Radio receiver
12. P command signal converter
13. Pulse delay oscillator
14. Sweep generator
15. Amplifier-decoder
16. Roll control amplifier
17. Amplifier bias control
18. Y steering amplifier
19. P steering amplifier
20. Heat exchanger
21. DC power filter

Figure 9. Radio set.

amplifier-decoder.

(3) The amplifier-decoder (fig 10) amplifies the incoming DC pulses and rejects false (incorrectly coded) signals. This prevents stray RF signals from another MTR giving commands to the missile. The amplified video pulses are fed to the pulse delay oscillator.

(4) The pulse delay oscillator (fig 10) receives the pulses from the amplifier-decoder and shapes them. The pulses are delayed and used to trigger a phantastron circuit that produces two outputs. One output, an enable gate pulse, goes to the sweep generator; the other, a burst gate pulse, goes to the fail safe control.

(5) The sweep generator (fig 10) uses the enable gate pulse to generate a P enable pulse or a Y enable pulse, depending on the command from the missile tracking radar. The P or Y enable pulses are sent to the command signal decoder.

(6) When the command signal decoder (fig 10) receives the P or Y enable pulse in proper sequence, it produces a P or Y trigger pulse that is applied to the respective P or Y command signal converter. The command signal decoder is composed of two identical channels. These channels operate alternately, since pitch and yaw commands are received alternately.

(7) Since P or Y command signal converters (fig 10) are identical, only the P will be discussed. The P trigger pulse from the command signal decoder is used to determine the amount of voltage generated for the magnitude and direction of the pitch command issued by the computer. A resulting plus or minus DC voltage is applied to the P steering amplifier. The DC voltage will be discussed during the steering phase of the guidance set.

(8) The fail safe control (fig 10) receives the burst gate pulse from the pulse delay oscillator. As long as the pulse is present, the missile warhead will not detonate.

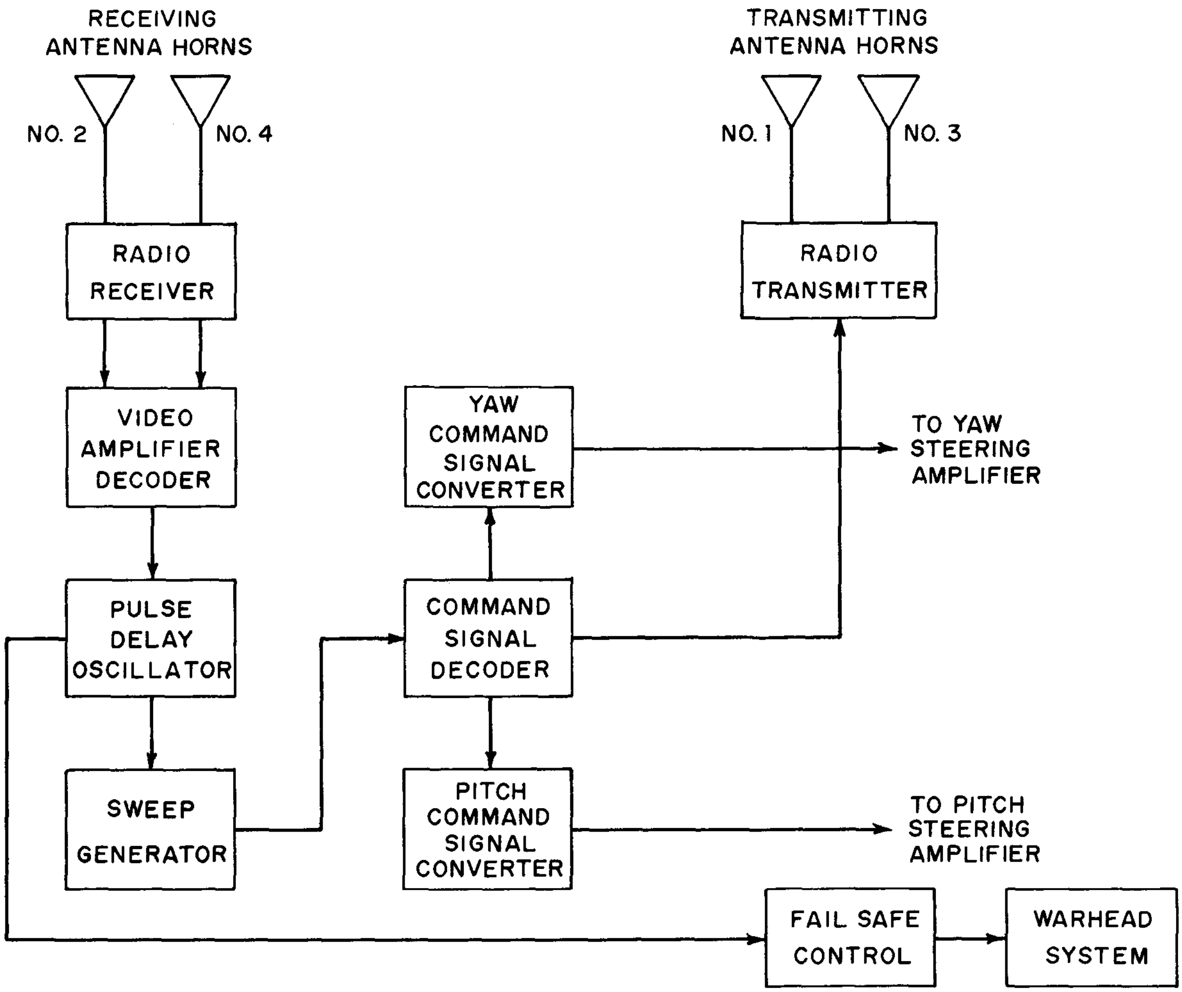


Figure 10. Nike missile guidance radio set block diagram.

When the missile tracking radar transmits a burst command, the burst gate pulse is removed. This allows a capacitor to discharge, applying sufficient voltage to the warhead system for detonation. If the missile guidance set malfunctions or if the ground guidance equipment malfunctions, the burst gate pulse is also removed, thereby detonating the warhead system (fail safe). This permits destruction of the missile and prevents the missile from falling into the hands of enemy agents.

(9) The command signal decoder (fig 10) generates one RF response pulse for every properly coded input pulse to the guidance set. The pulse is sent to the radio transmitter and antenna horns (No 1 and No 3) and radiated back to the MTR to insure continuous tracking of the missile until intercept of the target.

g. Flight control group and steering circuits. The flight control group (fig 11) continuously monitors changes in the missile's attitude, and sends compensating signals to the steering circuits (fig 12) to insure a smooth trajectory to the target. Yaw and pitch accelerations, roll amount and rate, and pressures acting on the flight control surfaces must all be considered before the proper missile response to commands can be established. The major components of the flight control group are: pitch (P) and yaw (Y) accelerometers; P, Y, and roll rate gyros; roll amount gyro; pressure transmitter; and fin feedback variable resistors. These devices feed data to the roll control amplifiers and the Y and P steering amplifiers to control the magnitude of elevon displacement.

(1) Basic gyro. Several of the flight control

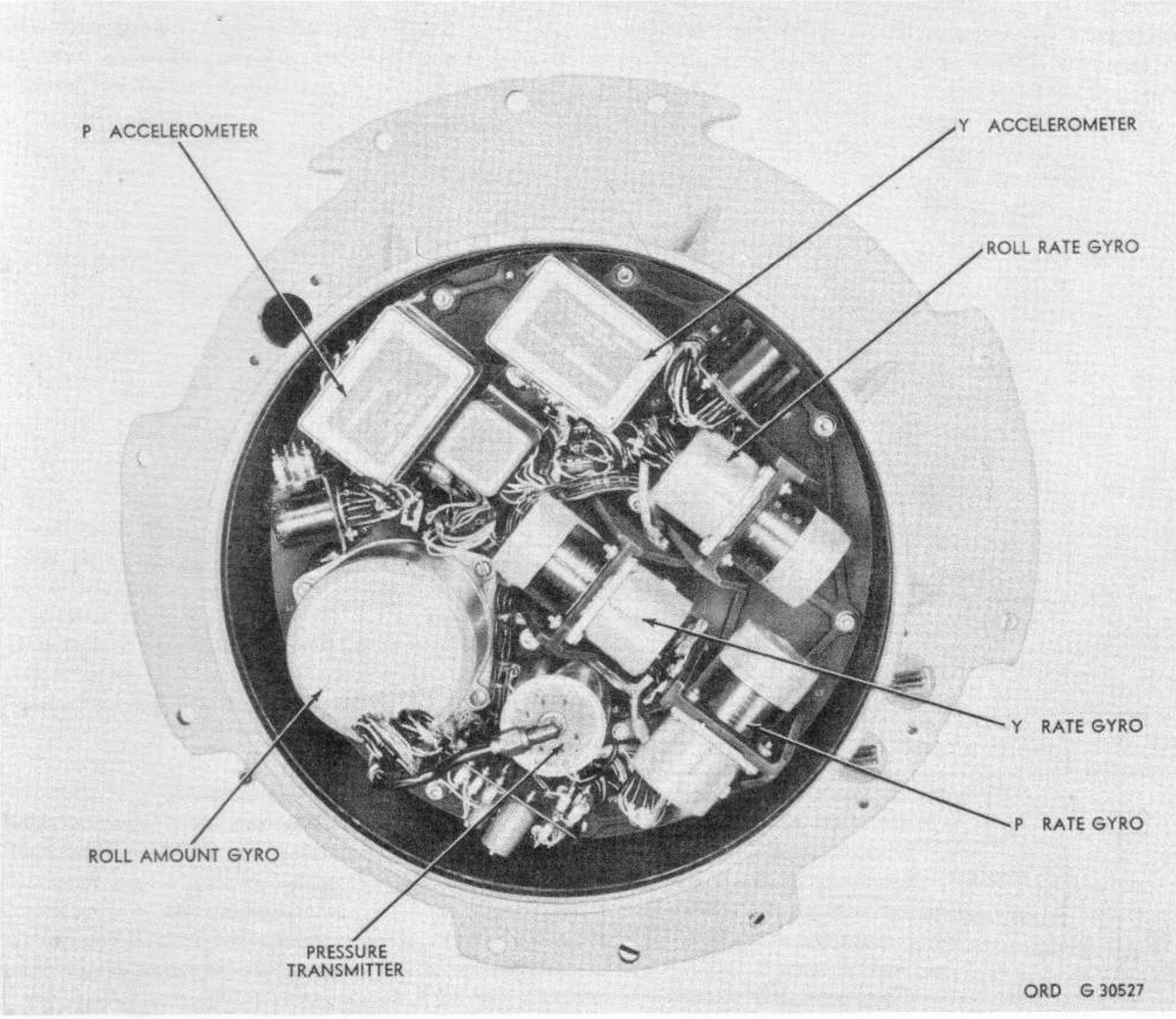


Figure 11. Flight control group.

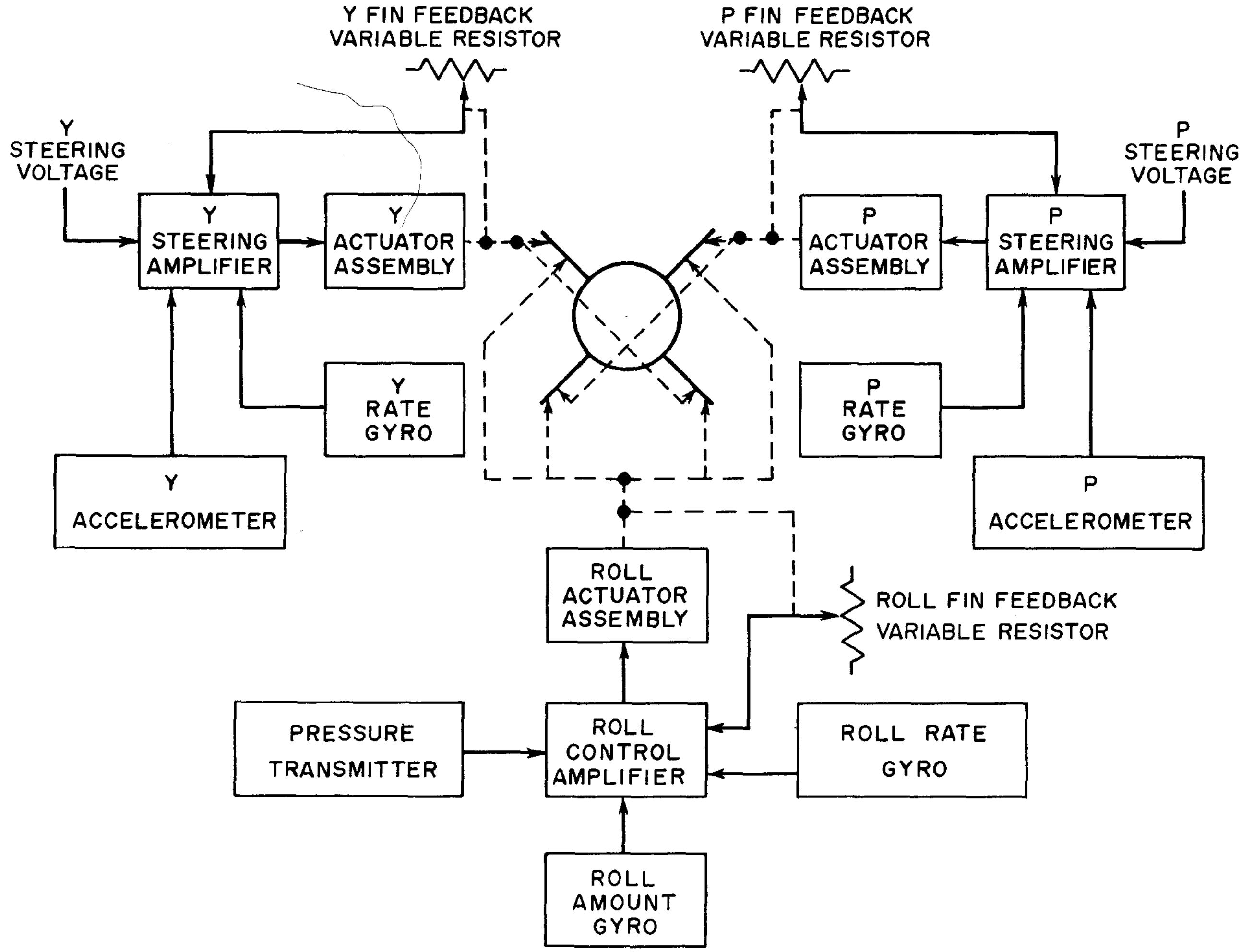


Figure 12. Steering control circuit block diagram.

instruments are gyros; therefore, lets first consider the operation of a basic gyro (fig 13).

(a) The gyro consists of a spinning rotor with its axle attached to a support frame called the inner gimbal. The inner gimbal is connected by an axle to the outer gimbal. Notice that the inner gimbal axis is in the same plane as the spin axis, but rotated 90°. Finally, the outer gimbal is connected by a third axle to the frame of the device being monitored, in our case the missile frame.

(b) Because of its angular momentum, the spinning rotor wants to maintain its position. If the base which the gyro is attached to turns around the inner or outer gimbal axis, the spin axis remains constant. A pickoff device, in our case a variable resistor, measures the magnitude of rotation of the base around the gimbal axis.

(c) To understand the principles of gyro operation, we must first consider two simple vectors: the spin vector and the torque vector. You will recall that a vector represents a physical quantity which has both magnitude and direction. For example, a velocity vector for an automobile has magnitude (miles per hour) and direction (north, south, east, west, or some combination of these). By contrast, speed by itself is not a vector quantity, but rather a scalar quantity. It has magnitude, but does not specify a direction.

(d) First lets consider the spin vector, an angular velocity that describes the magnitude and direction of the rotor rotation. The direction of the spin vector is found by using the right hand rule. Wrap the fingers of your right hand around the rotor so your finger tips point in the direction of rotation. Now, if you extend your thumb it will point in the direction of the spin vector (fig 14).

(e) The second vector to be considered is the torque vector. Torque is a force that tends to produce

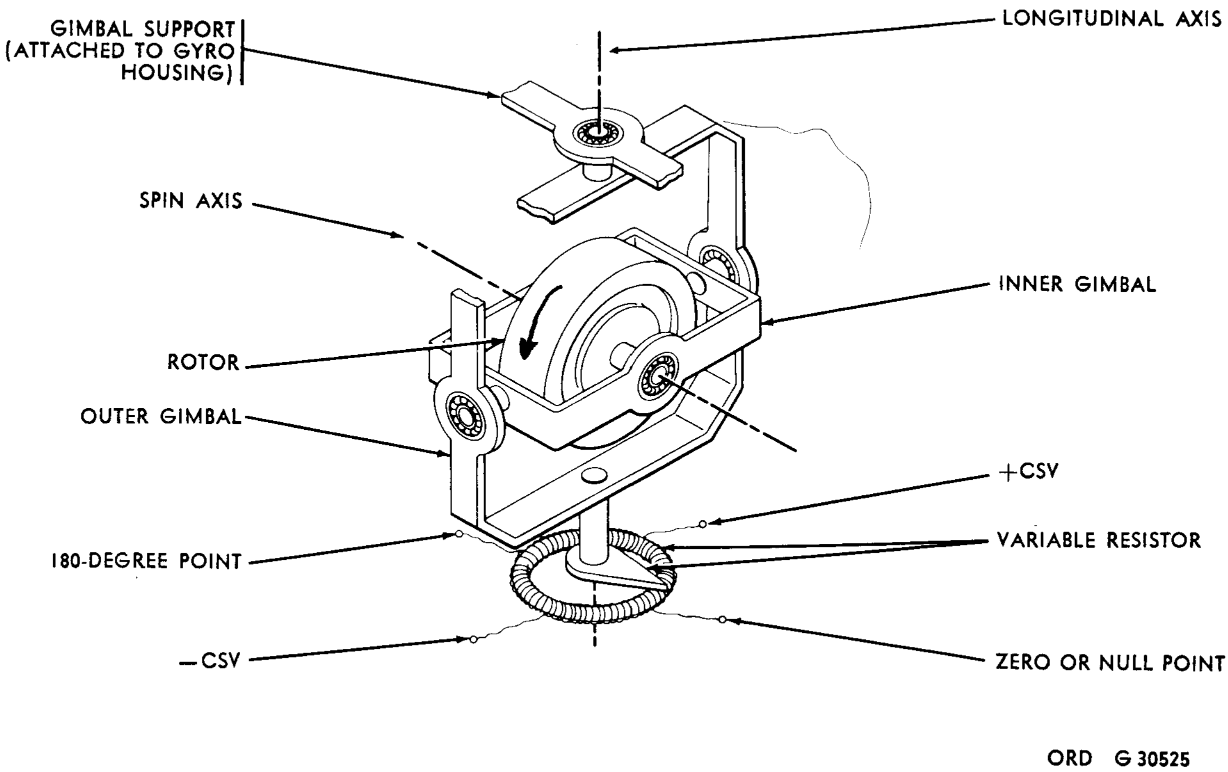


Figure 13. Basic gyro.

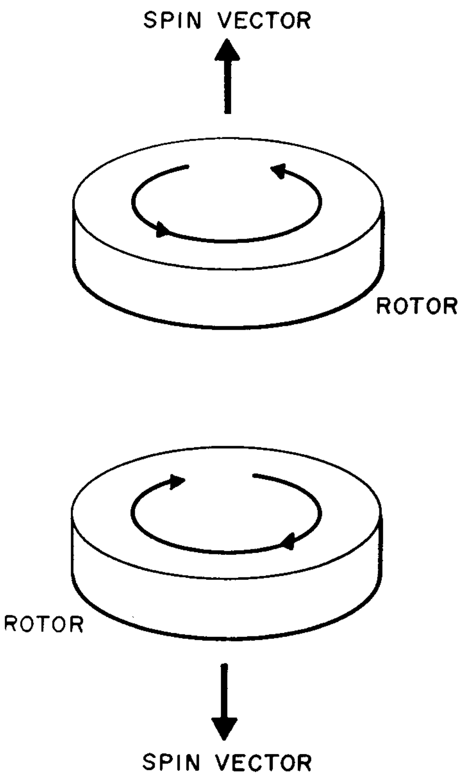


Figure 14. Spin vector direction.

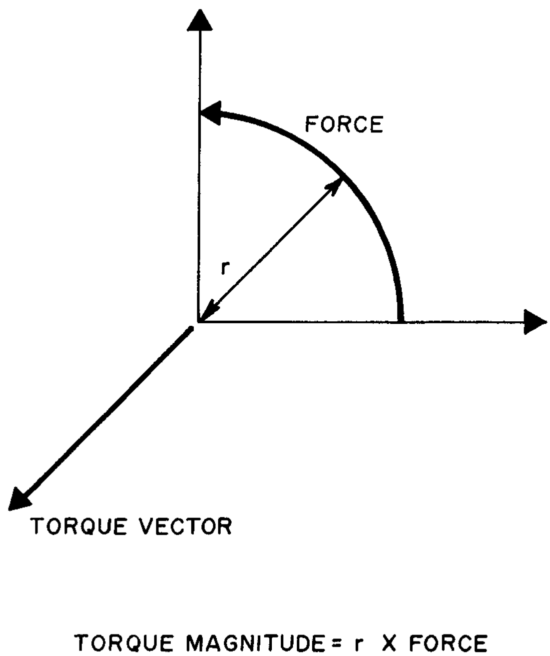


Figure 15. Torque vector magnitude and direction.

rotation. Torque magnitude is found by multiplying the force acting times its distance from the axis of rotation (fig 15). To find the direction of the torque vector, apply the right hand rule again. Wrap your fingers to point in the direction of the applied force, and your extended thumb will give the direction of the torque vector.

(f) Consider the gyro shown in figure 16. Its rotor is spinning clockwise; therefore, the right hand rule will tell us that the spin vector is pointing down. If a torque is applied around the inner gimbal axis as shown in figure 16, the torque vector is to the right. The law of gyroscopic precession states: *When a torque is applied to a gyroscope the spin vector tries to move into the torque vector.* Therefore, the gyro will rotate (precess) about the axis that is 90° from both the spin and torque vectors. This means when a torque is applied to the inner gimbal the outer gimbal rotates!!

(g) Conversely, if a torque is applied around the outer gimbal axis, the inner gimbal rotates. This condition is shown in figure 17. Apply the right hand rule, and verify the resulting precession.

(h) An extension of the right hand rule provides a handy aid in finding the direction of precession (fig 18). Arrange your thumb, index finger, and middle finger into a three dimensional co-ordinate system. The thumb represents the spin vector, the index finger then points in the direction of the torque vector, and the middle finger will provide the direction of the precession axis. If you rotate your thumb (spin) into the index finger (torque), your hand will move in the direction of precession.

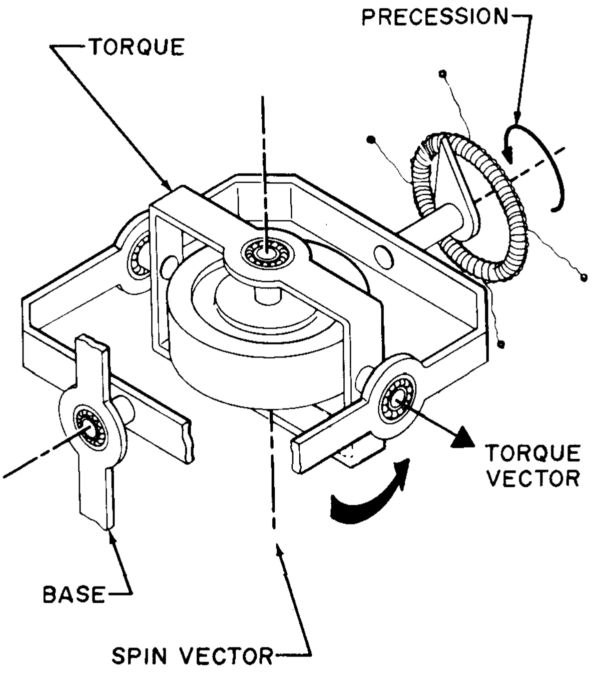


Figure 16. Torque applied around inner gimbal axis.

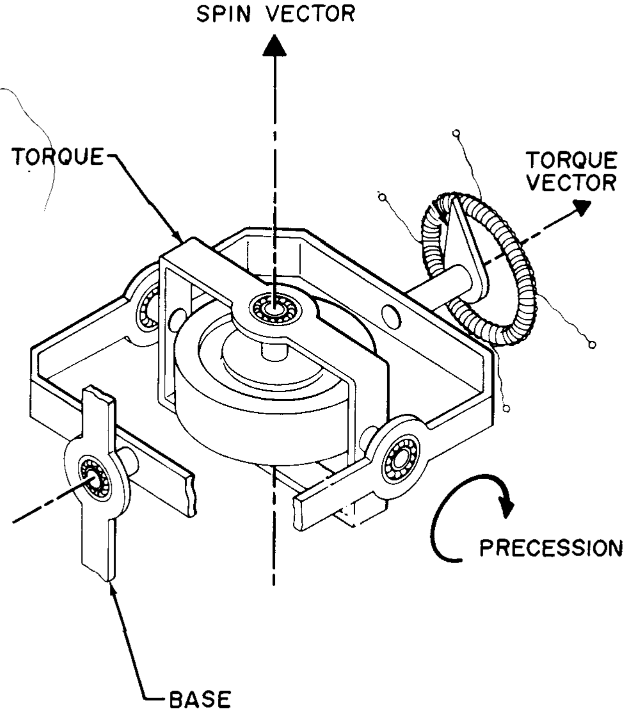


Figure 17. Torque applied around outer gimbal axis.

(i) If a pickoff device (pointer, variable resistor, etc) is placed on the gimbal axis, the angular change caused by a rotating base system (like the missile) may be measured. This is the basic "amount" gyro (fig 13).

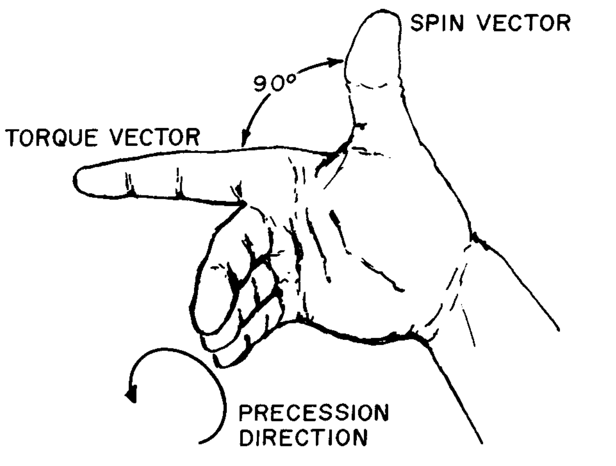


Figure 18. Right hand rule of gyroscopic precession.

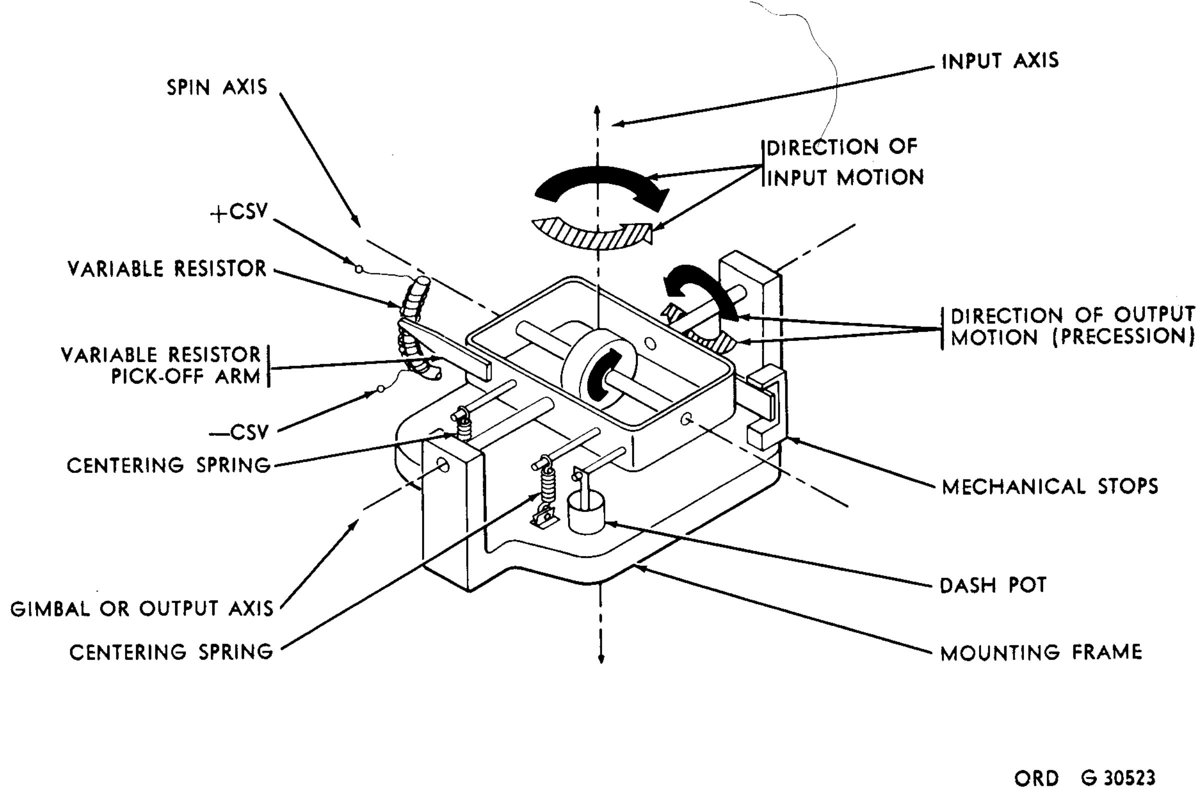


Figure 19. Simple rate gyro.

(j) The second type of gyro used in the missile is the rate gyro (fig 19). Instead of measuring the amount of precession, it measures the rate of precession. It has only one gimbal which is restrained by the centering springs. The centering springs stretch or compress in opposition to the acting torque. If the rate of precession is large, then the force acting on the gimbal is large and the spring is stretched or compressed a large amount. In this case, the pickoff arm is also deflected a large amount. Lesser forces make less headway on the spring, and the pickoff arm is moved a smaller amount.

(k) Notice that two of the three axis have different names on the rate gyro than they had on the amount gyro. The input axis is perpendicular to both the spin axis and the rest plane of the gimbal. The torque to be sensed is applied around the input axis. The third axis is the gimbal or output axis. The pickoff arm rotates about the output axis.

(l) The right hand rule locates the spin vector pointing toward the upper left corner of the diagram. An input torque as shown by the solid black arrow would produce a torque vector pointing down. With the spin vector rotating into the torque vector, the gimbal tends to precess around the output axis in a counterclockwise direction. The pickoff arm displaces downward. If the torque remains constantly applied, the gimbal will not continue to rotate but will find an equilibrium point as dictated by the opposing force of the spring.

(m) Using the torque direction shown by the shaded arrow in figure 19, verify that the direction of precession reverses.

(n) With the introduction of the centering springs, the gyro system becomes very susceptible to mechanical harmonic oscillation. The oscillations are dampened by the dash pot. Gimbal deflection is limited by the mechanical stops.

(2) Roll control circuits. It is the function of the roll control circuits shown in figure 12 to insure that the missile maintains a "belly down" attitude throughout the flight. Prior to launch, the computer presets the roll amount gyro toward the intercept point. During the boost phase roll correction does not take place because the elevons are locked. At booster separation the elevons are unlocked, and the output from the roll amount gyro roll stabilizes the missile with its belly pointed toward the intercept point. After roll stabilization, the computer issues the dive command, and the missile enters its controlled flight phase. During the controlled flight phase,

the roll attitude is monitored by the roll amount gyro. Any deviations from a belly down attitude are sensed by this gyro, which applies a correction voltage to the roll control amplifier. The amount of final control applied to the roll actuator assembly is modified by the roll rate gyro and pressure transmitter outputs. The roll fin feedback variable resistor provides a degenerative feedback used to return the elevons to zero command after roll compensation has taken place.

(a) Roll amount gyro. The roll amount gyro is of the type discussed in paragraph 4g(1)(a) through (i) above. Any roll movement displaces the pickoff arm on the variable resistor to produce an output voltage proportional to the magnitude of roll. The direction of roll determines the polarity of the voltage. The output voltage is applied to the roll control amplifier as the primary roll control signal.

(b) Roll rate gyro. The roll rate gyro is of the type discussed in 4g(1)(j) through (n) above. The output voltage magnitude of the roll rate gyro is proportional to the rate of roll. The polarity of the output is a function of roll direction. This voltage is in phase with the output of the roll amount gyro; therefore, it increases the response of the roll control circuits to oppose sudden changes around the missile roll axis.

(c) Pressure transmitter. The amount of elevon deflection required to execute a given amount of command is dependent upon the speed of the missile, and the atmospheric pressure acting on it (a function of altitude). The purpose of the pressure transmitter is to monitor the stagnation pressure (the sum of atmospheric and ram pressures), and initiate command magnitude modifying signals to compensate for pressure variations. The pressure transmitter (fig 20) uses two diaphragms placed end to end. Variable resistor wiper arms are attached to each of the two diaphragms. As the ram and/or atmospheric pressure varies, the expansion or contraction of the diaphragms will vary the wiper arms' positions a proportional amount. The output voltage from one variable resistor wiper arm controls the gain of the roll control amplifier. An increase in pressure decreases the gain of the amplifier, thereby decreasing the amount of elevon displacement. The second variable resistor controls the amount of input voltage applied to the fin feedback variable resistors.

(d) Roll fin feedback variable resistor (fig 12). The roll fin feedback variable resistor provides a degenerative feedback proportional to elevon displacement. This feedback signal closes the roll servo loop. If the roll command is less than two G's, the feedback signal will stop the elevons short of full deflection. As roll correction takes place, the feedback signal drives the elevons back toward the zero G position.

(e) Roll control amplifier (fig 12). The roll control amplifier receives and processes the outputs of the roll amount and rate gyros, the pressure transmitter, and the roll fin feedback variable resistor. The amplifier weighs and algebraically sums these inputs, and generates an output drive current to the solenoid operated control valve in the actuator. The hydraulic and mechanical components of the actuator then function to drive all four elevons to return the missile to its belly down position.

(3) Pitch and yaw control circuits (fig 12). The P and Y control circuits receive an input steering voltage from the command signal converters in the radio set (fig 10). As the missile responds to the command, P and Y accelerometers and rate gyros sense the movement and apply feedback voltages to the steering amplifiers to insure a smooth maneuver takes place. The P and Y control circuits are similar; therefore, only the Y will be discussed.

(a) Accelerometer. The yaw accelerometer monitors the lateral forces resulting from a yaw command. As these forces increase, the accelerometer applies a feedback voltage to the yaw steering amplifier, reducing the magnitude of elevon deflection. If the feedback control were not applied, the missile would tend to skid through the turn. Figure 21 shows a basic accelerometer consisting of a copper slug (pendulum), damping magnet, and output variable resistor. Suppose the missile's nose is in the upper left hand direction, and the support of the accelerometer is rigidly attached to the missile frame. If the missile makes a hard right turn, the accelerometer support would also turn right; however, the momentum of the copper slug would tend to keep it going in the original direction. Therefore, the copper slug would slide toward the lower left corner of the diagram, driving the variable resistor wiper arm toward the +CSV terminal. The damping magnet tends to hold the copper slug in its original position; therefore, the slug measures the force of the lateral movement referenced to the force of the magnet. The magnet also slows the movement of the slug, thereby lessening overshoot and oscillation.

(b) Rate gyro. The yaw rate gyro is of the type discussed in paragraph 4g(1)(j) through (n) above. The output voltage polarity of the yaw rate gyro is determined by the direction of the yaw maneuver. The magnitude of voltage is proportional to the rate of change in yaw.

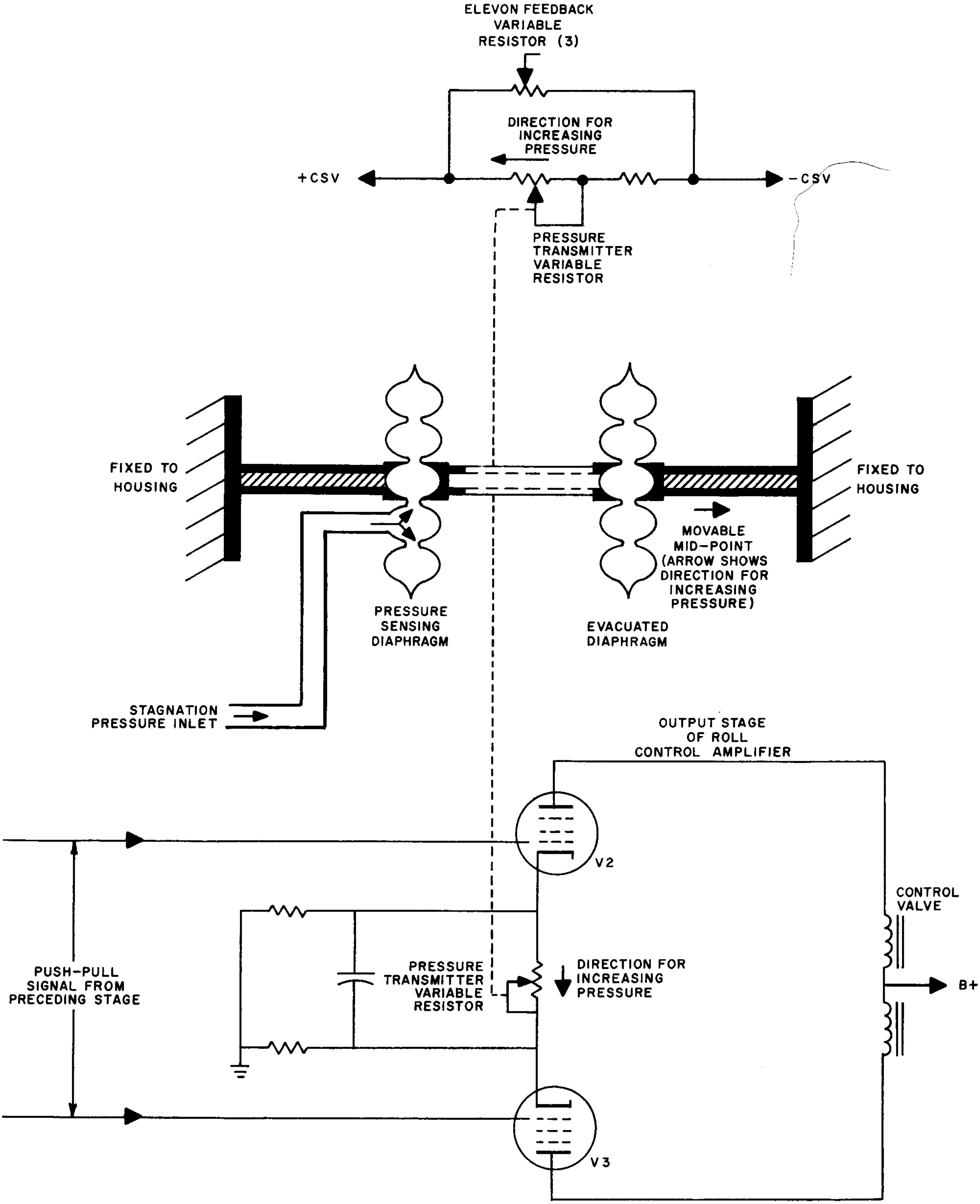


Figure 20. Pressure transmitter.

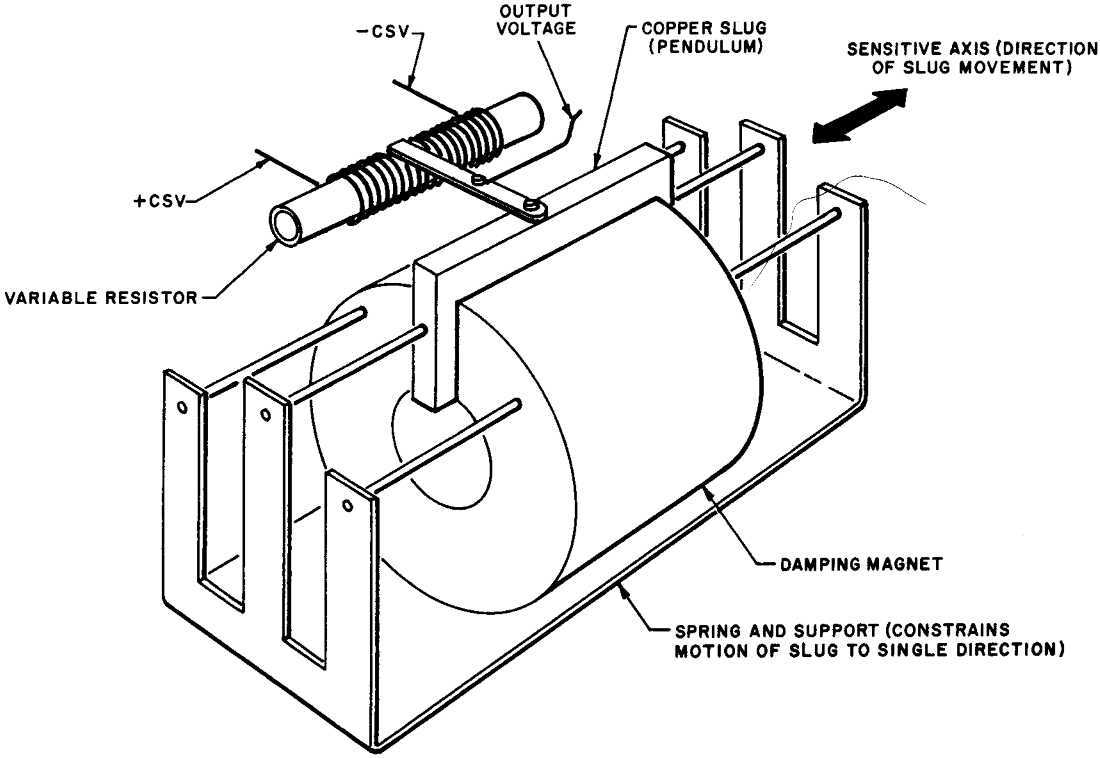


Figure 21. Accelerometer.

(c) Yaw steering amplifier. The yaw steering amplifier is the yaw output device of the guidance set. It provides the hydraulic system with the control signals required to execute yaw maneuvers. The yaw steering amplifier receives four input signals: (1) the steering order from the yaw command signal converter in the radio set, (2) the yaw accelerometer output, (3) the yaw rate gyro output, and (4) the feedback voltage from the yaw fin feedback variable resistor. These inputs are weighed and summed by resistive networks in the input circuits, and are applied to a push-pull DC amplifier. The DC (direct coupled) amplifier is an extremely high gain device which provides a large output current for a relatively low input voltage amplitude. Direct coupling is required because the input to the amplifier is a DC voltage (although it may vary in amplitude and polarity at a low frequency rate). Because the DC amplifier is connected in a push-pull configuration, two output current lines are provided. If the input to the amplifier is zero volts, the output currents are balanced. The currents unbalance for any input voltage other than zero volts. The direction of unbalance is dependent upon the input voltage polarity, and the magnitude of unbalance is a function of input voltage amplitude. The output currents of the DC amplifier flow through the solenoids of the missile control valve. The missile control valve then routes hydraulic fluid through the actuator, causing elevon deflection. Operation is initiated by the application of the steering order, its polarity indicating direction of yaw movement and its magnitude indicating the amount yaw required. The DC amplifier drives the actuator assembly, which in turn positions the elevons. The actuator also drives the fin feedback resistor's wiper arm an amount proportional to elevon displacement. This action provides a degenerative feedback voltage to the steering amplifier. As the missile executes its maneuver, outputs are developed by the Y accelerometer and Y rate gyro. These voltages are also applied to the steering amplifier to modify the amount of elevon movement. When the steering order returns to zero, the voltage on the fin feedback resistor wiper arm drives the elevon back to the zero command position.

(d) Pitch control circuits. The operation of the pitch control circuits is similar to that of the yaw control circuits. Of course, the P accelerometer and P rate gyro must be oriented with their sensitive axis positioned to monitor pitch movements.

5. **HYDRAULIC SYSTEM.** The hydraulic system (fig 22) converts the electronic commands into the mechanical forces required to move the elevons. The major assemblies of the hydraulic system are the P, Y, and roll actuator assemblies, the hydraulic pumping unit, and mechanical linkage.

a. General operation (fig 22). The signal inputs to

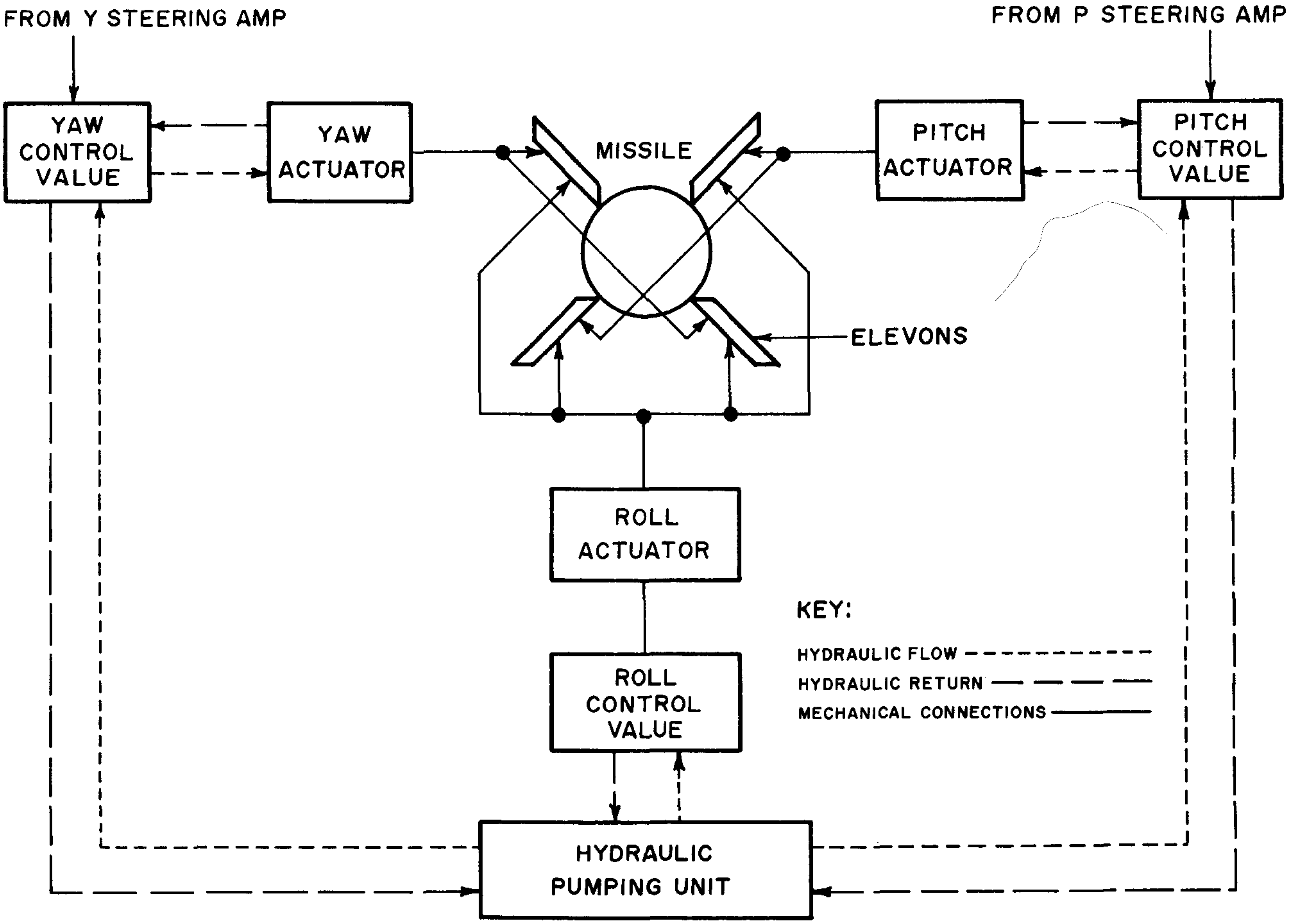


Figure 22. Hydraulic system block diagram.

the hydraulic system are applied to the three missile control valves. P and Y control comes from the P and Y steering amplifiers, and the roll signal comes from the roll control amplifier. The missile control valves are component parts of the actuator assemblies which mechanically drive the elevons. Steering commands cause movement of the proper P or Y elevon pairs. Roll commands cause movement of all four elevons. The hydraulic pumping unit provides hydraulic power for the actuators.

b. Actuator assemblies. The actuator assemblies (fig 23) converts the steering or roll commands into mechanical displacements by controlling the flow of hydraulic oil. The P and Y actuator assemblies are identical, and the roll actuator assembly differs only in the amount of output mechanical displacement. The major components of the actuator assembly are the missile control valve, actuator, and fin feedback variable resistor.

(1) The missile control valve (fig 24) controls the flow of hydraulic oil in the actuator. A spool valve (plunger) regulates hydraulic oil direction and flow rate to move the actuator piston, which is mechanically coupled to the elevons.

(2) With zero command applied, there is equal current flow in the two solenoids in the control valve. In this condition, the centering spring positions the plunger to block all hydraulic oil flow.

(3) The solenoids serve as plate loads for the output of the steering or roll amplifiers. Therefore, when a command is applied, the current flow in the solenoids becomes unbalanced, and the plunger displaces toward the solenoid having the greater current flow.

(4) Suppose the current flow in the right solenoid (fig 24) exceeds the current flow in the left solenoid. The plunger moves to the right as depicted in the figure. High pressure hydraulic oil from the Hydraulic Pumping Unit (HPU) is applied to the pressure port, and through the filter to the missile control valve. With the plunger pulled to the right, the hydraulic oil is routed out the lower right port to the actuator cylinder. The increase

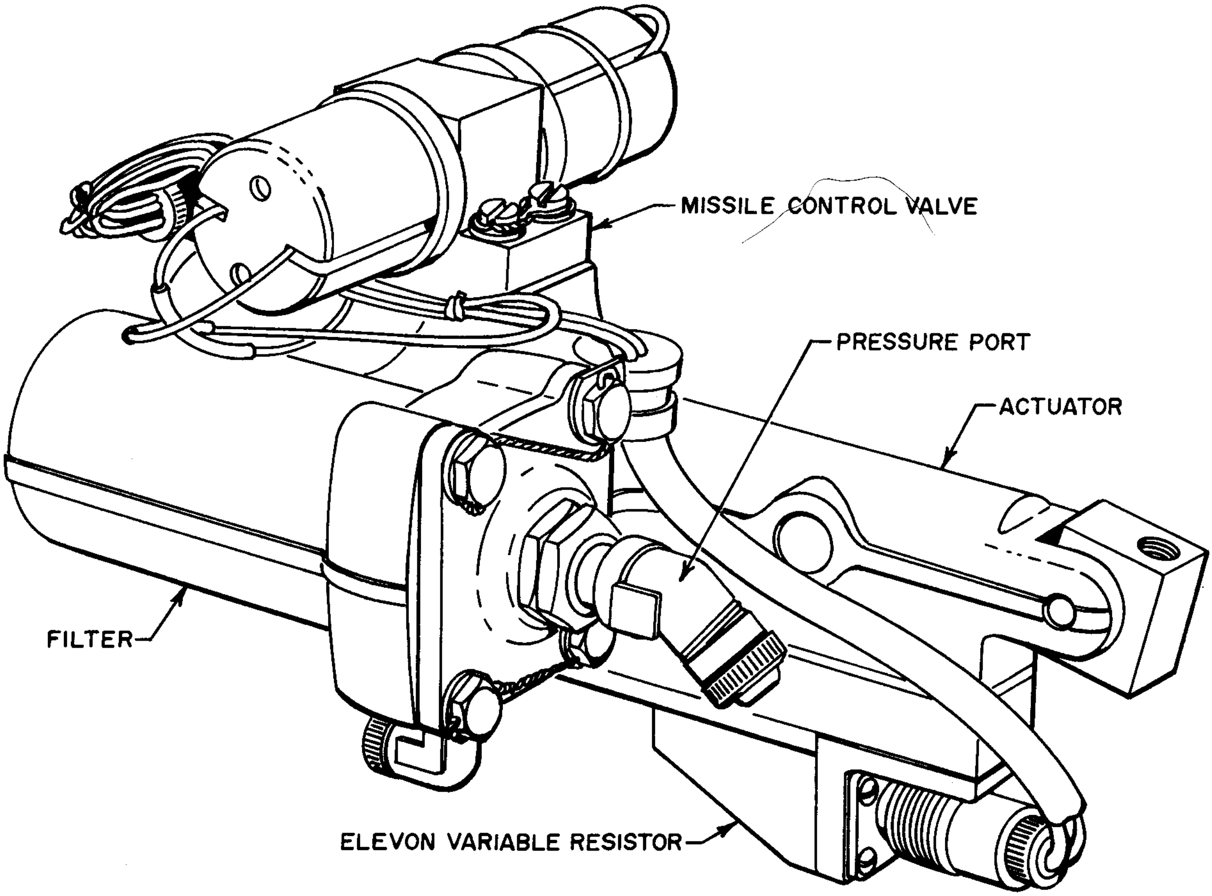


Figure 23. Actuator assembly.

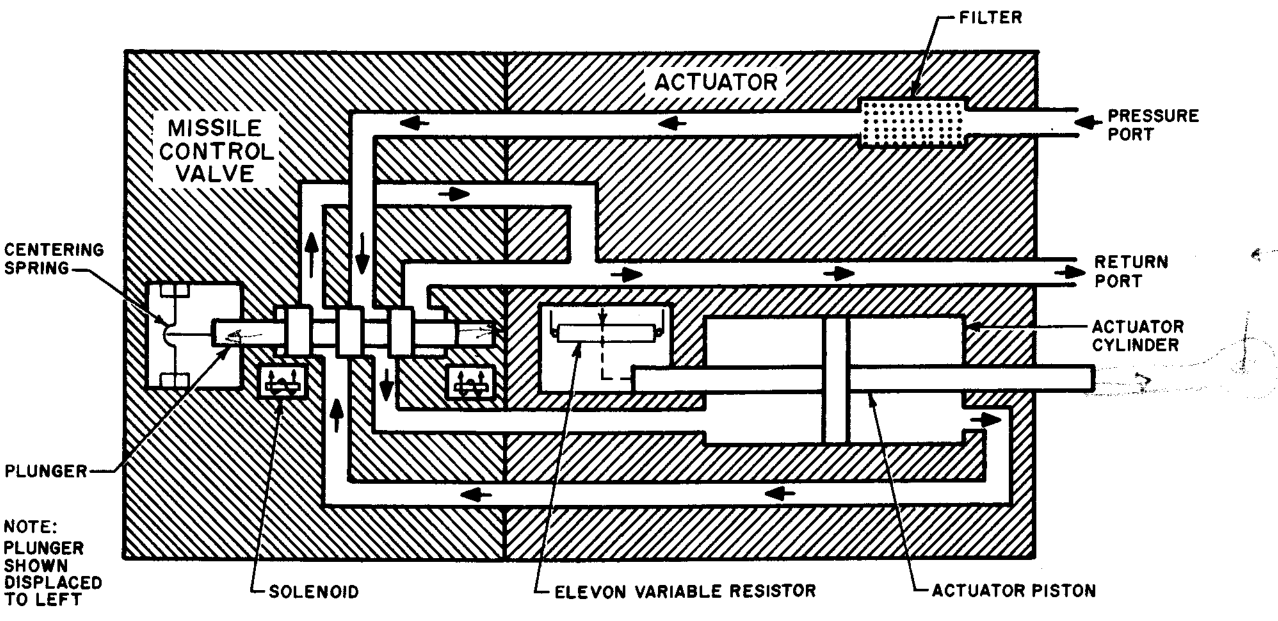


Figure 24. Actuator assembly operation.

in pressure moves the actuator piston to the right. Hydraulic oil is forced out the right side of the actuator cylinder, back through the missile control valve, and out the return port to the HPU. The actuator piston drives the mechanical linkage to the elevon, and positions the wiper arm on the fin feedback variable resistor. The fin feedback variable resistor applies a degenerative feedback to the steering or roll amplifier, which will equalize the currents in the solenoids. At this time, the plunger centers in the valve and the flow of hydraulic oil ceases. Notice that the command is still applied, the actuator piston remains displaced, and the elevon is left in its commanded position.

(5) When the command is removed from the steering amplifier, the fin feedback voltage unbalances the current flow in the solenoids in the opposite direction, and the plunger moves to the left. Hydraulic oil is now routed out the lower left port of the missile control valve, and enters the right chamber of the actuator cylinder. The actuator piston moves to the left, forcing the hydraulic oil in the left chamber back through the missile control valve and out the return port. As the actuator piston moves back toward its center position, the elevon drives toward the zero command position, and the fin feedback variable resistor output diminishes to zero. Once again the currents in the solenoids are equal, the plunger centers in the valve, and the flow of hydraulic oil stops.

(6) A low amplitude AC buzz voltage is applied to the missile control valves via the steering amplifiers. This small signal causes low magnitude alternating movements of the plunger, thereby overcoming static friction.

c. Mechanical linkage. The mechanical linkage system (fig 25) couples the actuator piston movements to the elevons. The P and Y mechanical linkages are similar and contain pushrods, beams, and bars. The roll linkage must control both the pitch and yaw elevons; therefore, it has a pushrod and bell crank connecting the roll actuator into the P and Y systems.

(1) The Y and P mechanical linkage is similar; therefore, only the Y will be discussed. Suppose the Y actuator (8) piston moves to the left (fig 25), thereby turning the Y bar (12) counterclockwise on its axis. The rotation of the Y bar (12) will cause the Y beam (11) to rotate in a counterclockwise arc (remaining parallel with the Y bar). This action pulls *both* Y pushrods (1) to the left, and deflects the elevons in a counterclockwise direction (as viewed from the top).

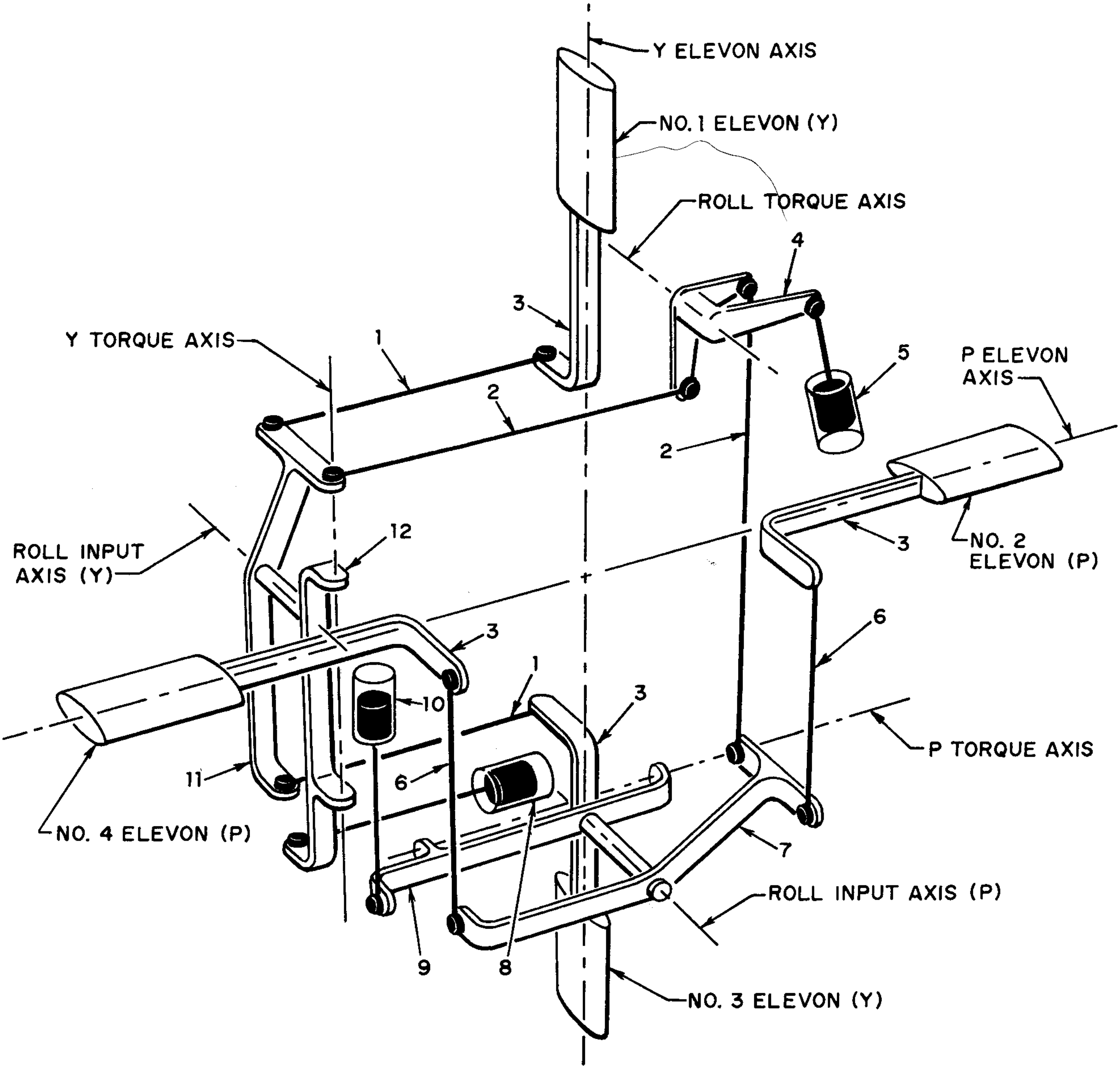
(2) Two factors make the roll linkage more complex than the P or Y linkage: (1) all four elevons must be controlled, and (2) each elevon in the pair (P or Y) is deflected in the opposite direction. Suppose the piston in the roll actuator (5) moves up or toward the top of the actuator as shown in figure 25. The roll bell crank (4) rotates in a counterclockwise direction and pulls the horizontal roll pushrod (2) to the right and the vertical roll pushrod (2) up. The pushrods couple into both the Y and P linkage systems. The horizontal pushrod rotates the Y beam (11) clockwise on the axis connecting the beam to the Y bar (12). This action drives Y elevon No. 1 clockwise, and Y elevon No. 3 counterclockwise. The vertical pushrod rotates the P beam (7) counterclockwise on the axis connecting the beam to the P bar (9). The P beam (7) acts through the P pushrods (6) to rotate the P elevons in opposite directions.

d. Hydraulic pumping unit (fig 26). The hydraulic pumping unit (HPU) is a battery-powered mechanism that provides hydraulic power for operation of the P, Y, and roll actuator assemblies. The HPU start command is applied automatically through the launching set during the firing sequence. The HPU power system shown in figure 27 utilizes a squib-activated battery to power a dc motor. The motor, in turn, drives a hydraulic pump. The power system also provides circuits to start the HPU, to monitor battery temperature, and to provide for ground operation of the unit. The HPU hydraulic system shown in figure 28 regulates hydraulic pressure developed in the pump.

(1) Hydraulic pumping unit (HPU) power system.

(a) The HPU utilizes a 28-volt dc squib-activated battery (fig 26), capable of supplying a maximum of 200 amperes to operate a dc motor which drives a hydraulic pump. The battery squibs are activated by 120-volt, 400-Hz power from the launching set during the firing sequence. Upon activation of the squibs, gas-generated pressure ruptures discs inside the battery and forces electrolyte through a manifold into the cells, activating the battery. Within 1.5 seconds after the battery is activated, full power is supplied to the motor.

(b) The 28-volt dc start command is applied through pin A (fig 27) of connector P143, closing the contacts of relay K513. The battery squibs are actuated by 120-volt, 400-Hz power applied through pin D of connector P143. Battery current actuates the pyrotechnic switch inside the battery, completing a circuit to illuminate the HEAT MONITOR indicator light on the launcher control-indicator panel.

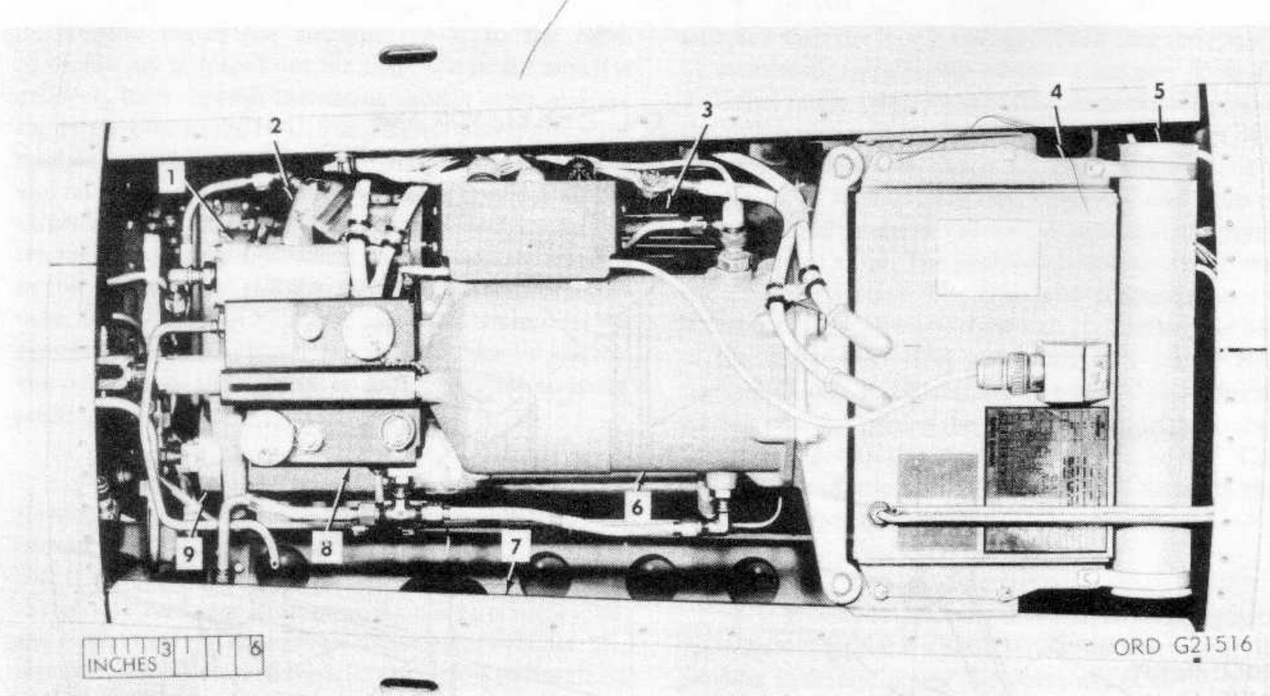


1. **Y pushrod (2 ea)**
2. **Roll pushrod (2 ea)**
3. **Shaft (4 ea)**
4. **Roll bell crank**
5. **Roll actuator assembly**
6. **P pushrod (2 ea)**
7. **P beam**
8. **Y actuator assembly**
9. **P bar**
10. **P actuator assembly**
11. **Y beam**
12. **Y bar**

Figure 25. Mechanical linkage system.

(c) Current to power the HPU battery heaters (fig 27) is supplied by an external power source. The heater control thermostats maintain the electrolyte container temperature at 115° F. The heater monitor thermostats close when the electrolyte container temperature decreases to 100° F. If the temperature decreases to 100° F, the HEAT MONITOR indicator light on the launcher control-indicator panel illuminates.

(d) During ground operation, the HPU is supplied external power through a power supply truck (power conversion unit). A motor temperature switch (fig



1. **Manifold assembly**
2. **Pump**
3. **Motor**
4. **HPU squib battery**
5. **Ventilator assembly**
6. **Low-pressure accumulator**
7. **Equipment section**
8. **Indicator panel**
9. **High-pressure accumulator**

Figure 26. Hydraulic pumping unit.

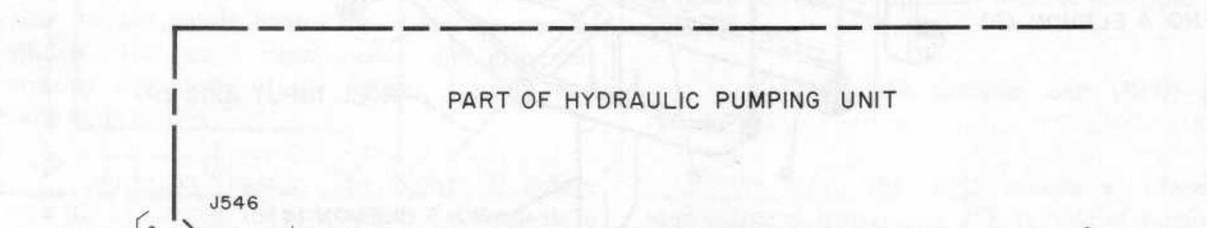


Figure 27. Hydraulic pumping unit, electrical schematic.

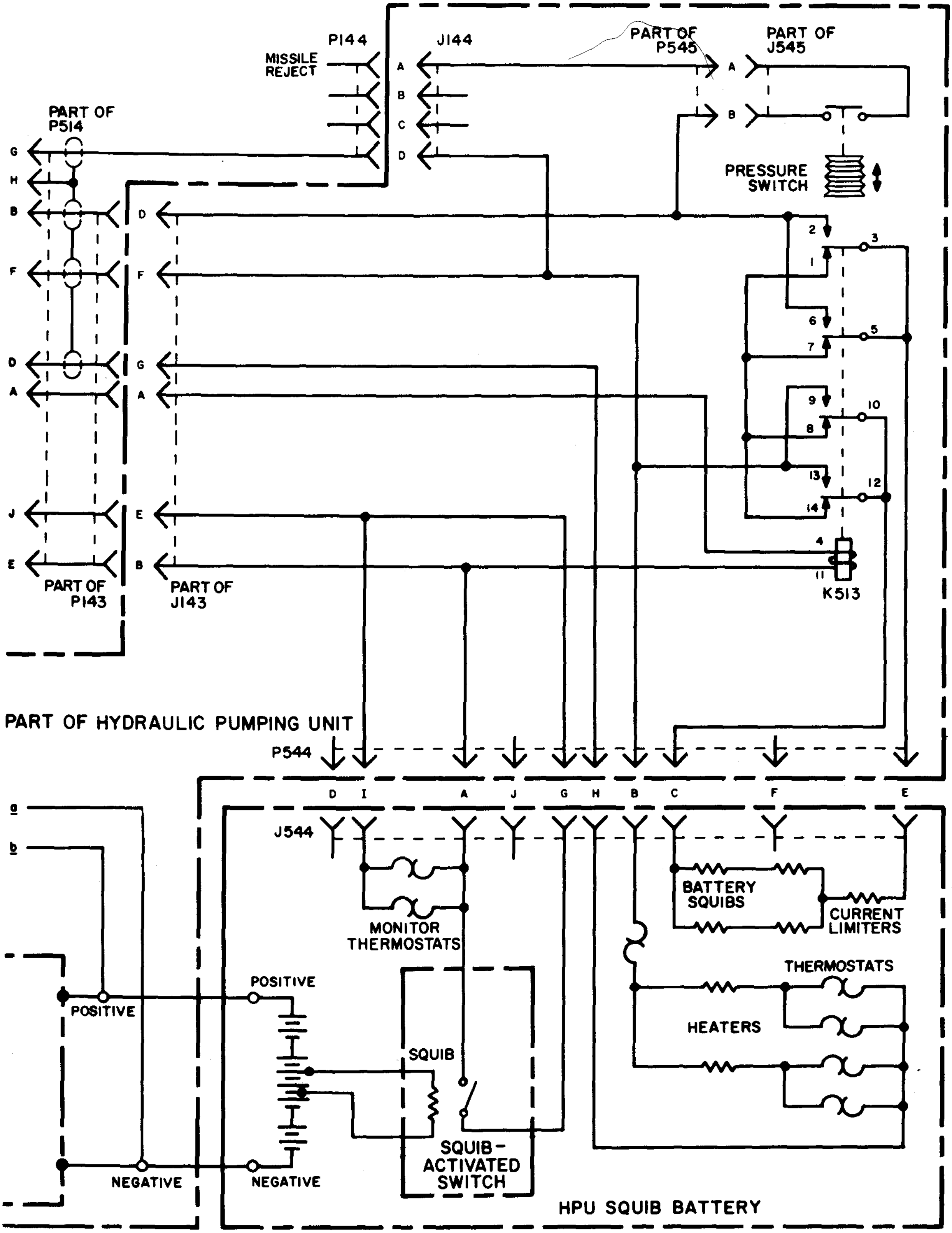


Figure 27. Hydraulic pumping unit, electrical schematic (Con't).

27) and an accumulator oil temperature switch in the low-pressure accumulator are also provided for ground operation. If the oil temperature exceeds 195° F, the accumulator temperature switch opens, turning off the external power automatically through the power supply truck. If the motor temperature exceeds the thermoswitch cut-in temperature (302° F minimum), the motor temperature switch opens, turning off the external power automatically through the power supply truck.

(2) Hydraulic pumping unit (HPU) hydraulic system.

(a) General. The hydraulic system of the HPU (fig 28) regulates the flow of high-pressure oil between the hydraulic pump and the P, Y, and roll actuator assemblies, maintaining the oil flow at a pressure of 2,700 to 3,200 psi.

(b) Operation. The low-pressure accumulator (cylinder) (fig 28) contains a differential area piston (air on one side, oil on the other) which provides the pump with a pressurized oil supply and absorbs a portion of the heat generated by the hydraulic system during HPU operation. Immediately after the HPU is started, oil is transferred by the pump from the low-pressure accumulator to the high-pressure accumulator, making high-pressure oil available to the P, Y, and roll actuator assemblies. The accumulator air pressure gage indication increases from the initial precharge pressure to 2,700 to 3,200 psi. The high-pressure accumulator stores hydraulic oil under pressure generated by the pump so oil pressure demands by the actuators may be satisfied. The accumulator also dampens pressure surges occurring from the pump. The high-pressure relief valve relieves the pressure of the pump if the pressure compensator, which maintains the pump outlet pressure between 2700 and

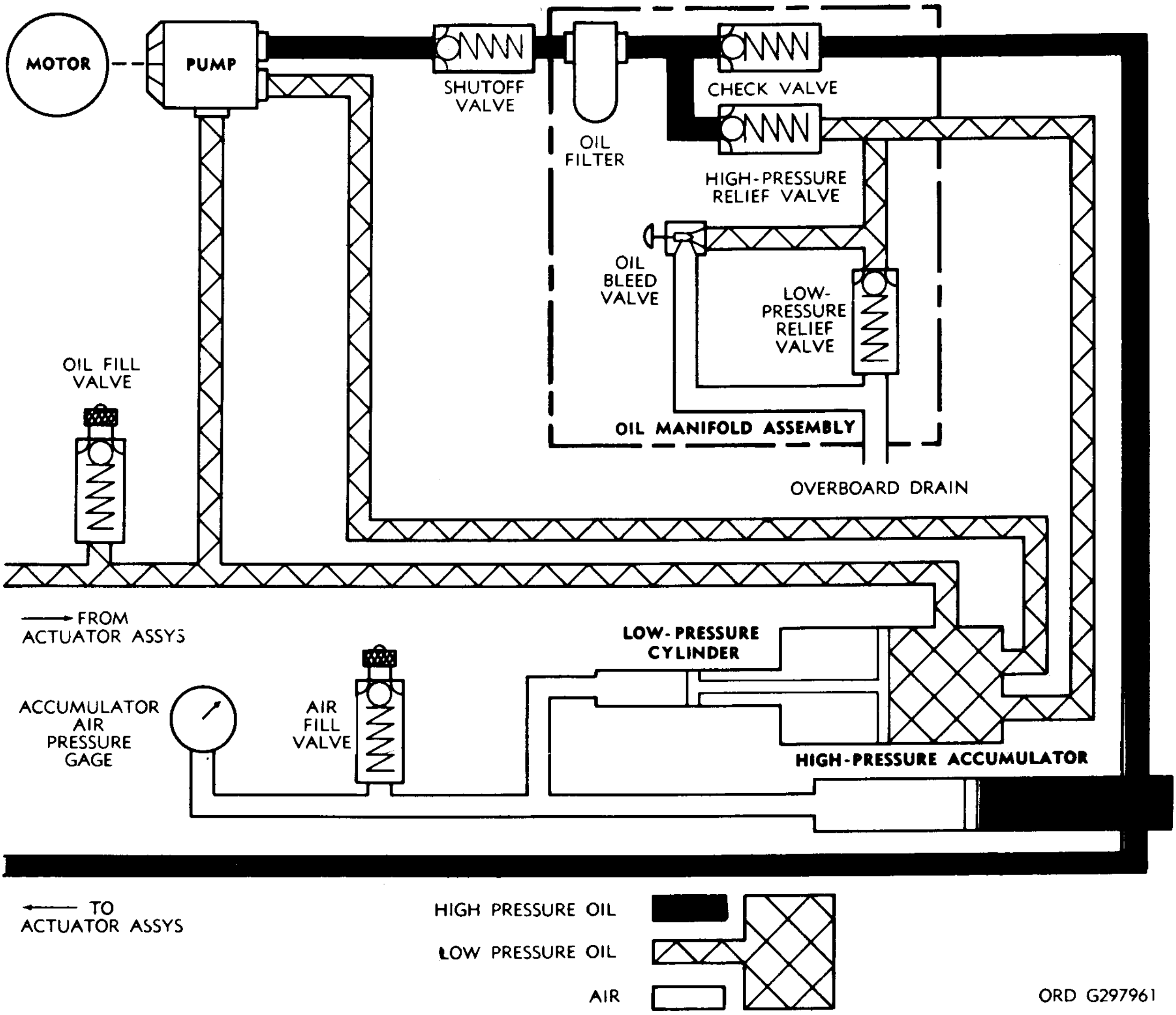
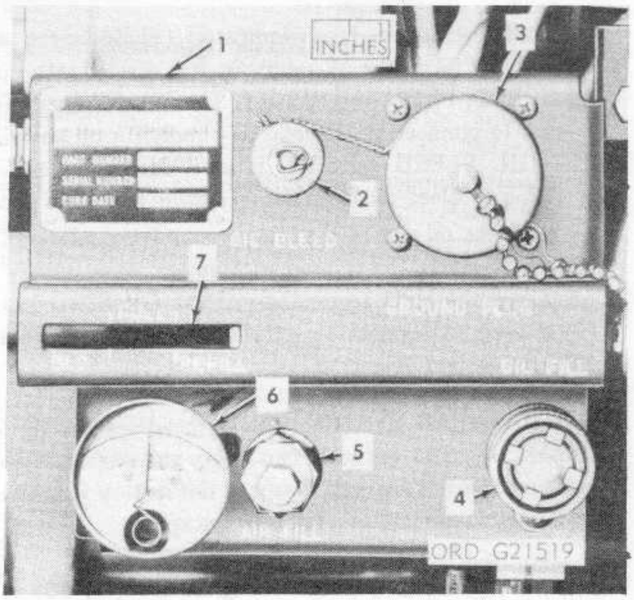


Figure 28. Hydraulic pumping unit, hydraulic schematic.

3200 psi, fails to function properly. In case of pump malfunction, the relief valve provides a 3700-psi differential pressure at 2.5 gpm flow, bypassing oil to the low-pressure accumulator. The low-pressure relief valve prevents oil pressure in the reservoir from exceding 160 psi during servicing operations. The check valve prevents the high-pressure accumulator from rotating the pump in reverse. After unit shutdown, the oil flows from the high-pressure accumulator through the actuators to the low-pressure accumulator by the application of buzz voltage. When the high-pressure accumulator is completely depleted of oil, the accumulator air pressure gage indicates the air precharge pressure.

Note. Key numbers shown in parentheses in (c) below refer to figure 29.

(c) HPU controls and indicators. All controls and indicators for servicing and inspecting the HPU are located on the indicator panel (1). The accumulator air pressure gage (6) indicates the pressure of the air contained in the high- and low-pressure accumulator pressurizing cylinders. The lower scale of the gage is calibrated in pounds per square inch and is used during operation to indicate the hydraulic pressure developed by the HPU. The upper scale is calibrated in degrees Fahrenheit and is used during air servicing to indicate when the air accumulator is pressurized to the required value for the existing ambient temperature. The



1. **Indicator panel**
2. **Oil bleed valve**
3. **Ground plug**
4. **Oil fill valve**
5. **Air fill valve**
6. **Accumulator air pressure gage**
7. **Hydraulic reservoir level indicator**

Figure 29. Hydraulic pumping unit, indicator panel.

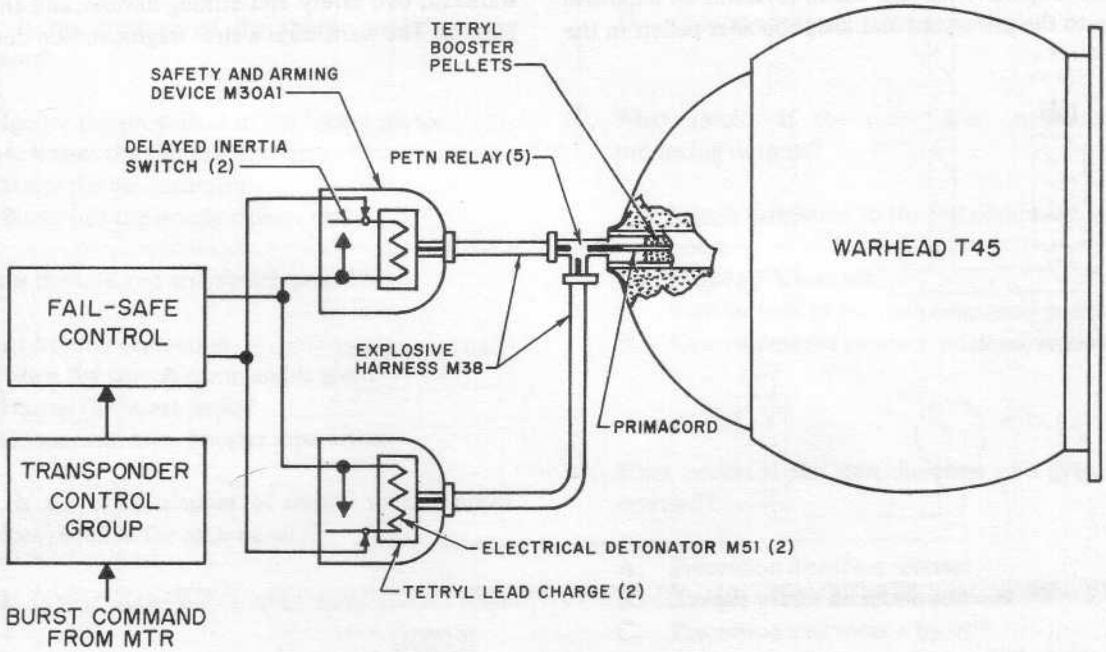


Figure 30. T-45 Warhead.

hydraulic reservoir level indicator (7) indicates the quantity of oil in the oil reservoir. It is divided into three areas: BLD, FULL, and REFILL. The OIL FILL valve (4) is used to connect an external oil supply for oil servicing. The OIL BLEED valve (2) is used during air and oil servicing to bleed air from the oil system and drain excess oil from the oil side of the low-pressure accumulator. The AIR FILL valve (5) is used to connect an air supply to precharge the HPU accumulators. The GROUND PLUG (3) is used to connect an external power supply to the HPU for ground operation.

6. **WARHEAD SYSTEM.** The warhead system (fig 30) consists of a T45 warhead, two safety and arming devices, and an explosive harness. Warhead detonation is initiated by a burst command or a fail safe voltage.

a. The safety and arming device (fig 30) is a plug-in, fuse-type mechanism that functions as a detonator and a safety device. The safety and arming device consists of a delayed inertial switch, an electrical detonator, and a tetryl lead charge. The safe and arm switch is armed during the boost period by the force of acceleration on the inertial switch. In the armed condition (as shown) a short circuit is removed from the input to the detonator. Under this condition, the explosive charge may be initiated by a voltage from the fail safe control.

b. The explosive harness (fig 28) consists of two lead assemblies. Detonation of the electrical detonator ignites the explosive harness which serves as an explosive coupling to the primacord and tetryl booster pellets in the warhead.

c. The T-45 warhead is a steel fragmentation device. It is detonated by the primacord and tetryl booster pellets.

7. **SUMMARY.** The Nike Hercules missile has five functional systems: (1) Rocket Motor Cluster, (2) Missile Rocket Motor, (3) Guidance System, (4) Hydraulic System, and (5) Warhead system.

a. The rocket motor cluster is a solid propellant booster unit consisting of four rocket motors. It supplies the initial thrust at launch, and burns for about 3 seconds.

b. The missile rocket motor is ignited upon booster separation. It provides the final thrust to the intercept of the targets.

c. The guidance system receives commands from the MTR, and generates control signals for the hydraulic system to control the missile's flight attitude. The guidance system consists of the radio set and the flight control group.

d. The hydraulic system provides the mechanical drive for the elevons. Its major units are the P, Y, and roll actuator assemblies, the HPU, and mechanical linkage.

e. The warhead system consists of the T-45 warhead, two safety and arming devices, and an explosive harness. The warhead is a steel fragmentation device.

EXERCISES FOR LESSON 2

1. What prevents motion between the Nike Hercules missile and the rocket motor cluster?

   A. Elevon locks
   B. Propulsion arming lanyard
   C. Resonance rods
   D. Indexing pin

2. What insures uniform propellant burning in the rocket motors?

   A. Resonance rods
   B. Nozzle closure
   C. Insulation coating
   D. Inhibited cellulose acetate liner

3. What is done to prevent accidental ignition of the rocket motor propellant during shipment?

   A. A shorting connector is applied to the igniters
   B. The igniters are removed
   C. The propellant is shipped unmixed
   D. The propellant is saturated with water

4. What is the purpose of the missile rocket motor initiators?

   A. Ignites the propellant in the rocket motor
   B. Activates the thermal batteries
   C. Starts the gas generator
   D. Blows out the nozzle closure seal

5. When is the safe and arm switch armed?

   A. At booster separation
   B. When the launch command is given
   C. During the boost period
   D. One second after booster separation

6. What is the total number of missile rocket motor initiators required for each missile?

   A. 1
   B. 2
   C. 3
   D. 4

7. What command does NOT originate from the ground guidance equipment?

   A. Pitch
   B. Yaw
   C. Burst
   D. Roll

8. What command controls all four elevons?

   A. Pitch
   B. Yaw
   C. Burst
   D. Roll

9. What circuit prevents the Nike Hercules missile from responding to commands generated by an MTR of another system?

   A. Amplifier decoder
   B. Pulse delay oscillator
   C. Sweep generator
   D. Command signal converter

10. What results if the pulse delay oscillator quits producing outputs?

    A. Missile continues to the last computed intercept point
    B. Warhead detonates
    C. Elevons lock in the zero command position
    D. Yaw commands produce pitch movements

11. What occurs if the spin direction of a gyro rotor is reversed?

    A. Precession direction reverses
    B. Torque vector direction reverses
    C. Precession axis rotates by 90°
    D. Spin vector tries to move *away* from the torque vector

12. What would result if one of the centering springs on a rate gyro were broken?

A. Gimbal never returns to center position
B. Gimbal displacement is less than normal for a given input rate
C. Output voltage is greater than normal for a given input rate
D. Gyro breaks into mechanical harmonic oscillation

13. What signal is applied to the steering amplifiers, but NOT the roll control amplifier?

A. Fin feedback variable resistor output
B. Rate gyro voltage
C. Amount gyro voltage
D. Accelerometer output

14. How many actuator assemblies are contained within the missile?

A. 1
B. 2
C. 3
D. 4

15. When is the hydraulic system activated?

A. At booster separation
B. During the firing sequence
C. During the boost period
D. After the missile roll stabilizes

16. What condition MUST exist for the plunger in the missile control valve to be centered?

A. Equal currents flowing in the solenoids
B. Zero command into the steering or roll amplifier
C. Fin feedback variable resistor wiper arm centered
D. Elevon positioned to zero command

17. What supplies hydraulic oil to the actuators?

A. Squib battery
B. Power conversion unit
C. Low-pressure accumulator
D. High-pressure accumulator

18. What command(s) causes opposite elevons in the elevon pair to deflect in opposite directions?

A. Roll
B. Yaw
C. Pitch
D. Yaw and pitch applied together

19. What is the purpose of the buzz voltage?

A. Operates the HPU pump motor
B. Detonates the warhead
C. Reduces static friction in the control valves
D. Ignites the rocket motor initiators

20. How many lead assemblies are contained in the explosive harness of the warhead?

A. 4
B. 3
C. 2
D. 1